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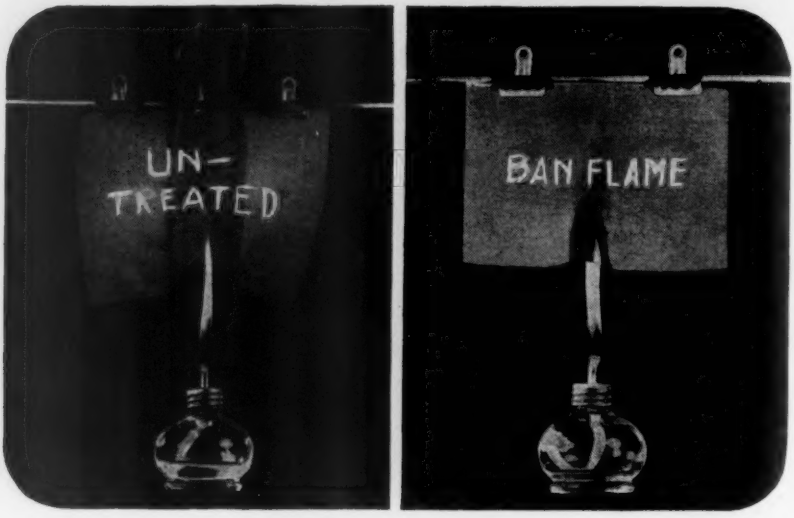

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THE EVOLUTION OF RAIN.

BY

W. J. HUMPHREYS.

To most of us, perhaps, the way nature produces a shower of rain may seem to be too obvious to merit a second thought. But it is not so simple as that, indeed so far from obvious that it has evoked a good many second thoughts, one of which is more minutely explained here than previously elsewhere.

We know, starting at the beginning, that unreplenished water in an open outdoor vessel gradually disappears, though the vessel be free from any leak and the water protected from every visible source of loss.

We also know, by experiment, that the water that fills one-fourth, or any other considerable portion, of a completely closed vessel does not all disappear however long it is left alone, but does decrease in direct proportion to any increase in the volume of the vessel, and also with, to an extent well-known, but not in direct proportion to, any increase in the temperature of the vessel and its contents. Furthermore, experiment shows that the amounts of these changes in the quantity of the contained liquid water are but little modified by the presence of ordinary air at whatever pressure, even down to where no air is left, just vapor.

We, therefore, can say correctly that at any stationary stage, the free space in the vessel is saturated with water vapor at its then temperature, or we may say, incorrectly, and commonly do, that the air in the vessel is saturated with water vapor at its then temperature.

Seemingly, therefore, water can be gotten out of the free air, which always contains, or consists in part of, water vapor, either by compressing that vapor (and unavoidably the rest of the air constituents with it) to and below its saturation volume, or by cooling it (and incidentally the other gases with it) to below its saturation temperature. But, as implied, these apparently inevitable results do not always follow. They

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do in the presence of a free water surface and in the open atmosphere around about us, but not in purified air; that is, air cleaned of all foreign substances, such as traces of acids, microscopic, or smaller, particles of sea salt, and dust motes in general.[1] Condensation of water vapor in such clean air to droplets does not occur until normal saturation—saturation in the presence of a flat surface of pure water—has been passed several fold. Nor does it begin at the same degree of humidity on motes of all sorts—on some it starts even before saturation is attained, and on some others not until it is well passed. However, since, as shown by experiment, the open air always contains a superabundance of these condensation nuclei, the question of condensation in clean air may be wholly ignored so far as the production of rain is concerned.

Increase of pressure never is sufficient to cause much condensation, except occasionally, perhaps, in the form of a fog. The other process, cooling, by which nature gets water out of the air is effected in four important ways: (1) By contact with cold surfaces, the cause of dew. (2) By radiation loss, of, say, a nearly saturated portion or layer of the air, the major cause of land fogs. The extent to which this occurs in the midair is not known, but it scarcely can be productive of rain. (3) By admixture of colder with warmer air, the principal cause of sea fog. Under favorable conditions some cloud also can be produced in this way, but not enough, as explained in Humphreys' "Physics of the Air," and elsewhere, to be important as a cause of rainfall. (4) By work, incident to expansion against the surrounding pressure by ascending air. This is essentially the sole cooling process by which moisture in the air is precipitated as rain or snow.

The ascent of a mass of air may result from the converging of wind currents; from interference by a mountain, or a body of colder air, in the path of a wind; from its uplift incident to being underrun by oncoming colder air, as along a cold front; or by thermal convection incident to local heating, as in the heat thunderstorm; or to "latent" heat freed by condensation.

Now experiment shows that the number of condensation nuclei in the open air that are operative when the humidity is pushed several per cent. beyond saturation, commonly ranges from 100 to 1,000, or more, per cubic centimeter. Hence, we might expect rising air, containing, say, 10 to 20 grams of water vapor per cubic meter, to become filled with a dense cloud of droplets, all far too small to fall as rain. How, then, and that is where the answer is not so obvious, do raindrops form in rising air, as assuredly they must for rain does fall out of it?

It has been suggested that the larger droplets must fall down through the cloud they are in and pick up all other droplets in their paths, and

[1] For this fact, and a number of others relative to condensation nuclei, see especially, collected scientific papers of John Aitken.

thereby emerge as good-sized raindrops. On first thought this theory may seem plausible, and presumably it does apply in the production of most warm-front rains, discussed presently, after those induced by much stronger convections have been considered; but rain does not always and automatically so result as is evident from the fact that even large summer cumuli often float along for hours without yielding any perceptible rain at all—the capture drops must somehow first be built up to fall size. How this is done is explained later.

Another theory to account for the growth of the raindrop assumes that the larger top droplets, on falling through the cloud, all the time grow by condensation incident to their continuous lower temperature than that of the air they currently are in.

A still different theory rests on the fact that owing to surface tension larger drops grow at the expense of close-by smaller ones.

Each of these last two theories is qualitatively correct, but a little calculation, based on reasonable assumptions, shows that a particle falling through a cloud cannot grow to raindrop size by either of these ways. However, for the present purpose neither of these calculations is necessary, as many clouds themselves give the answer by floating for hours at a time without yielding a drop of rain.

An entirely different theory in this connection assumes that all raindrops result from the melting of snow crystals on the route of their fall through the lower and warmer air. Of course, often raindrops are formed by the melting in midair of snowflakes, but this does not help much, for the difficulty now is to explain why snowflakes are so few in comparison with the vast number always present of possible condensation nuclei. Besides, the presence of snow crystals clearly is not essential to the formation of raindrops, since, as shown by airplane records, often rain falls from clouds whose highest parts still are below the freezing level.

It appears, then, that rain, whether as melted snow or as liquid water from its inception, falls only out of clouds formed in *rising* air that contains rather a large amount of water vapor. Evidently this air usually carries hundreds, at least, of foreign particles per cubic centimeter, ranging from the distinctly hygroscopic that deliquesce even before saturation is quite attained on to those that collect moisture only in the presence of supersaturation. Obviously in such rising air the more hygroscopic particles are the first to collect moisture and form cloud particles—liquid droplets or ice crystals. These, of course, are carried up, at first, when extremely minute, nearly as rapidly as the air they are in is ascending, but are followed by others similarly caused that thereby keep (temporarily) the cloud so formed and the level of its base unchanged however the constituent particles may be moving. From the start, though, they normally rise slower and slower, owing mainly to their increase in weight incident to condensation onto them

of water vapor from the supersaturated (with reference to them) air they currently are in (not that in which they started or had been, but continuously following air)—supersaturated by virtue of cooling with ascent—and which blows up past each particle with the same speed that it would fall through that air at rest.

Assuming, now, absence of a snow phase: when, but not until, a drop, through condensation, or coalescence with one or more other drops, or both, has become so large that the lift (push, pull, and drag) on it by the rising air—increase of pressure below, decrease of pressure above, and tug of skin friction on the side—can take it no higher, it floats at its then level (widely different for drops of different size) until, in a moment or two, its additional gain in weight, through further condensation or otherwise, starts it slowly down, falling so long as this gain (proportional to the increase in the volume of the drop) keeps ahead of the simultaneous gain in the lift (for drops above mist size, say 0.1 mm. in diameter, lift increases with the increase in the projected area of this drop, increase in density and viscosity of the passing air, and increase in the square of the velocity of impact of this air against the drop). Hence, the obvious fact that the actual velocity of descent of a drop is that at which it would fall in the adjacent air, if that air were at rest, less the up-velocity of this air.

When the up-velocity of air of sea level density is around 30 feet per second, or inversely greater for air of less density, raindrops cannot fall through it at all, but on reaching a diameter of about half a centimeter are ruptured with much production of electric separation, the cause of lightning and thunder.

Obviously the droplets formed in the ascending air capture vast numbers of the foreign particles in it—partially purify it by a filtering process, while the falling drops also scour it all the way down to the ground. Snow crystals, also, similarly cleanse the air.

Owing, then, jointly, to the restriction of condensation to the more hygroscopic nuclei; the filtering of the rising air by the less rapidly rising droplets; and its further filtration or scouring by the falling drops, all the way down from their greatest heights, the number of effective nuclei becomes so limited—so small a fraction of the total number of all nuclei that reach the base of the cloud—that the vapor present is sufficient to build about them drops of appreciable size, rather than, if equally divided among all the entering nuclei, a dense cloud of microscopic droplets, such as forms in an Aitken cloud chamber when suddenly pushed to its maximum effect.

Clearly, furthermore, in a region of strong updraft, a raindrop produced wholly by condensation starts descending only at some level well above that of maximum potential life, that is, the level at which the up-velocity of the air is greatest, or near that level; while one formed in part by coalescence starts falling at a lower level. Each, of course,

continues to descend where, but only where, its weight is greater than the lift on it incident to the velocity of ascent of the rising air. But the farther down into denser and denser air, towards the level of maximum lift, the drop falls, owing to gain in weight incident to growth in size, and the faster it falls, the greater the lift on it. Hence, these two forces, weight and lift, must be roughly equal to each other at the level of maximum lift. At this level, then, the weight of a drop (porportional to the cube of its radius) must be equal to a numerical factor times the area of its equatorial cross section (proportional to the square of the radius of the drop) times half the density of the adjacent air times the square of the velocity of impact between the drop and air, all in proper units. Now, where convection is vigorous, this impact velocity is equal, approximately, to the up-velocity of the rising air, and as this velocity and the density of the air have, each, roughly constant values over an appreciable area at the time of a steady rain, the dominant raindrops at that time and over that same area necessarily are of nearly equal size, as indicated by observation and confirmed by measurement. Indeed, measurements have shown even more than this—that, grouped in order of size, there is at least one additional maximum number of drops, each of about the mass of two of the dominant ones, formed, doubtless, by coalescence of the latter, incident, in some cases, to mechanical jostling, and in others to sidewise collisions induced by the Bernoulli force, the force that pushes the baseball out of its wonted course.

The velocity of ascent of air of a given density and stated temperature necessary to just support a drop of a particular size can be computed, but for our present discussion this is not necessary. However, it may be said, in passing, that at the height of 2 kilometers above sea level it is about 5 meters per second for drops one millimeter in diameter and 8 meters per second for drops 2 millimeters in diameter.

It remains now to consider the formation of drops in warm-front rains where the up-slope ascent is only around 15 centimeters per second —enough, however, to support drops at and below the height of 3 kilometers, say of about the size of those in a fine mist. Hence, smaller drops than these cannot fall out of air at these levels having this velocity of ascent while larger ones must fall out. Furthermore, the droplets in the top layer of this cloud presumably gain in size faster than do those at any other level, owing to coalescence incident to turbulence, which drives the smaller droplets against the relatively large and therefore, owing to their greater inertia, comparatively stationary drops that do not so closely follow the devious turbulence course of the air, and which turbulence appears to be greatest at the upper surface of the cloud. Clearly, now, a droplet, however formed, falling though such a cloud and capturing, as we may assume it would, every particle of liquid water it encounters would grow in size all along its course. To compute the

rate of this growth let r be the radius of the drop and A its projection area, or area of its equatorial cross section, and let it fall the minute distance df, normal to the base of the cloud where the b^{th} part of the space is occupied by liquid water. By this fall the drop therefore will capture a correspondingly minute quantity dw of water given by the equation

$$dw = Ab\ (df).$$

This amount of water added to the drop increases its radius by the minute amount dr, given by the equation—the surface area of a drop (sphere) being 4 times its projected area,

$$dw = 4A\ dr.$$

Hence,

$$dr = \frac{b}{4}\, df.$$

If, now, the cloud contains 2 grams of liquid water per cubic meter, a fair average value, then

$$dr = df/2 \times 10^6.$$

Hence, a mist droplet starting down at the top of such a cloud half a kilometer thick would come out as a raindrop half a millimeter in diameter. If the cloud were one kilometer thick, the drop would be one millimeter in diameter.

Therefore, in each relatively quiet portion of a warm-front rain also, the drops are of nearly uniform size, relatively small where the cloud is thin and larger where it is thicker, though only exceptionally, perhaps, more than one millimeter in diameter.

The other common forms of precipitation, hail, sleet (small round ice pellets), snow, require but little explanation, as to origin, beyond that for rain. Hail needs, in addition, only violent and irregular ascent of the air; sleet, a low layer of air cold enough to freeze raindrops falling through it; and snow, air temperatures below the freezing point. To be sure, there are details about each of these that might be discussed at length, but such discussions would be foreign to the purpose of this article—to explain the evolution of rain, and to show why the number of its drops is so small in comparison with that of the condensation nuclei in the lower free air.

A PREVIEW OF THE WESTERN UNION SYSTEM OF RADIO BEAM TELEGRAPHY.*

BY

COLONEL JULIAN Z. MILLAR, B.S.E.E.

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PART I.

As has been reported in the newspapers, Western Union plans to establish super-high-frequency radio systems between the major cities in the United States during the next seven years. These radio systems, over which telegrams are to be transmitted, ultimately may replace the trunk pole lines with their hundreds of thousands of miles of wire in the present telegraph network.

Western Union assisted in the construction of an experimental radio relay circuit between New York and Philadelphia in the spring of 1945 in cooperation with the Radio Corporation of America, and with the approval of the Federal Communications Commission. This venture was successful and proved conclusively that radio relay telegraph transmission, which we like to call Radio Beam Telegraphy, is a feasible and economical means of operation. The Company has now received FCC licenses to establish a triangular radio system connecting three cities, New York, Washington, and Pittsburgh, and for a second circuit connecting New York and Philadelphia. Factory production of equipment is under way, and as soon as it is installed, commercial telegrams will begin to flow over these new facilities, experimentally, pending authority from the Commission for permanent commercial operation.

Before describing the methods which have been devised for transmitting more than a thousand telegrams simultaneously in each direction on a radio beam circuit, let us examine some of the wire line practices which are now being used.

The first experimental model of the electro-magnetic telegraph was shown before the Franklin Institute in 1838, by Samuel F. B. Morse. Since this time, practically all operation has been accomplished by equipment connected to the opposite ends of single wires grounded at each terminal. The wire lines generally follow railroad rights of way, short sections of lead-covered cable being used in congested areas. In recent years copper wire has replaced most of the iron wire originally employed.

* Presented Before the Franklin Institute, February 20, 1946.

Improvements in design, and careful maintenance, have kept these facilities at a very satisfactory level of efficiency, but like all transmission mediums, wire lines are subject to certain inherent limitations and difficulties. The difficulties of a physical nature are caused by sleet storms, floods, fires, and railroad or vehicular wrecks. Periodic patrol is required to keep the insulators in good condition and the wires from contacting one another. Falling branches, the corrosion of splices, and the boy with the kite or a piece of wire, all spell occasional trouble for the lineman.

From a transmission viewpoint, the electrical characteristics of grounded single wire lines are of greater importance. While a few hundred cycles of signalling frequency spectrum can be obtained, it is the noise or interference which determines the distance over which transmission will be satisfactory. Interference arises from several sources. The most troublesome electrical disturbances are currents induced by conductive or inductive coupling with power and railway systems, and lightning, and during a magnetic storm, currents which flow through the earth. Currents in neighboring telegraph circuits induce interference in the working circuit, especially when the ground connection is faulty. Another noise factor is any imperfection in the duplex balancing network which is necessary to simultaneous transmission in both directions over a single wire.

In the Morse period, the speed of operation was largely determined by the skill of the operator, but when semi-automatic keys were used no operator was permitted to use a sending speed higher than 11 dots per second.

With the advent of printing telegraph equipment, beginning in the year 1900, signalling frequencies were approximately doubled for single teleprinters, and increased by a factor of eight times for other equipment.

Figure 1 is a picture of a teleprinter of the page printing type. It is ordinarily used in customers' offices and at outlying points in the telegraph network. At an operating speed of 65 words per minute, the line signals consist of seven 22 millisecond units. One group of signals is required for every letter transmitted. Another type of teleprinter prepares a printed tape which is gummed to the blank.

Simultaneously, there developed economic pressure to extend circuits across the continent, and to obtain a larger message volume from each circuit. The first of these requirements was satisfied by the development of the regenerative repeater, which completely restores the signal to its original form at each repeater point. The invention and use of the Multiplex provides a method for transmitting more messages per circuit. By a process of time division, the Multiplex divides the available circuit capacity into two, three or four parts. It is the system being used on most trunk circuits in operation today.

Figure 2 is a photograph of a multiplex distributor table showing the face-plate end of the synchronous distributors which are used to transfer the line signals to the teleprinters and to assemble the outgoing signals from the perforators and automatic transmitters. Some of the plugs are shown removed from the sockets to illustrate the facility with which the distributors can be replaced. The brushes are driven by synchronous motors which are controlled by electrically-driven tuning

FIG. 1. Teleprinter.

forks. The mechanical displacment of the brushes on the receiving distributor is slowly altered to agree with the exact time of arrival of the signal from the distant sending distributor. The multiplex may operate as rapidly as 75 words per minute per sub-channel, in which case the shortest line pulse is only 6.7 milliseconds in duration.

A variation of the Multiplex is the Varioplex, which provides for the interconnection of as many as 40 single teleprinters by one 4-channel Multiplex circuit. In this system, full speed is attained by a maximum of only four simultaneous transmissions—if more than this number of

sub-channels become active, the speed of each is reduced. The chief virtue of the Varioplex is that a larger number of lightly-loaded circuits may be concentrated on one trunk signalling channel. By proper assignment, each customer is given the equivalent of a private wire at low cost, and full-speed operation is guaranteed for a high percentage of the time.

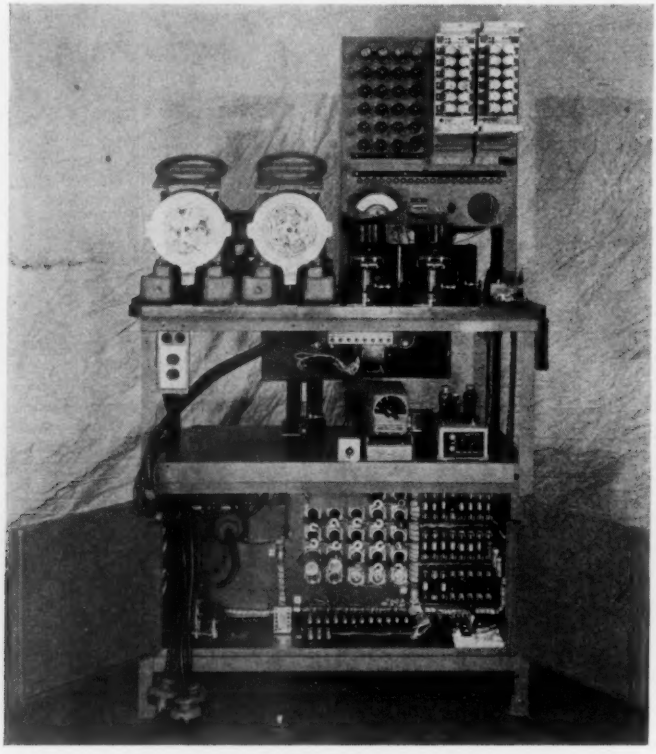


FIG. 2. Multiplex Distributor Table.

Figure 3 is a view of a six sub-channel Varioplex set. At the right is the Multiplex distributor table. The teleprinters which are connected to this system would be located in operating rooms or at customers' offices. The Varioplex equipment racks can be extended to the left to include as many as 40 sub-channels. It will be noted that a perforated tape is employed to transfer the signals from the sub-channels to the trunk Multiplex.

Telegram transmission by facsimile methods is now receiving considerable attention. The Western Union Telefax offers the advantage of higher accuracy in transmitting typed messages, and the ability to reproduce advertising copy, pictures, handwriting, and drawings. A Telefax transmission may be accomplished in from 1 to 5 minutes, de-

pending upon the size of the message, the definition desired, and the frequency band width of the signalling channel.

Figure 4 is a photograph of a Telefax drum type transmitter-receiver. The message to be transmitted is placed on the drum by the operator, and it is then scanned photo-electrically. When receiving, a Teledeltos recording paper blank is wrapped around the drum, and a facsimile reproduction of the message is obtained.

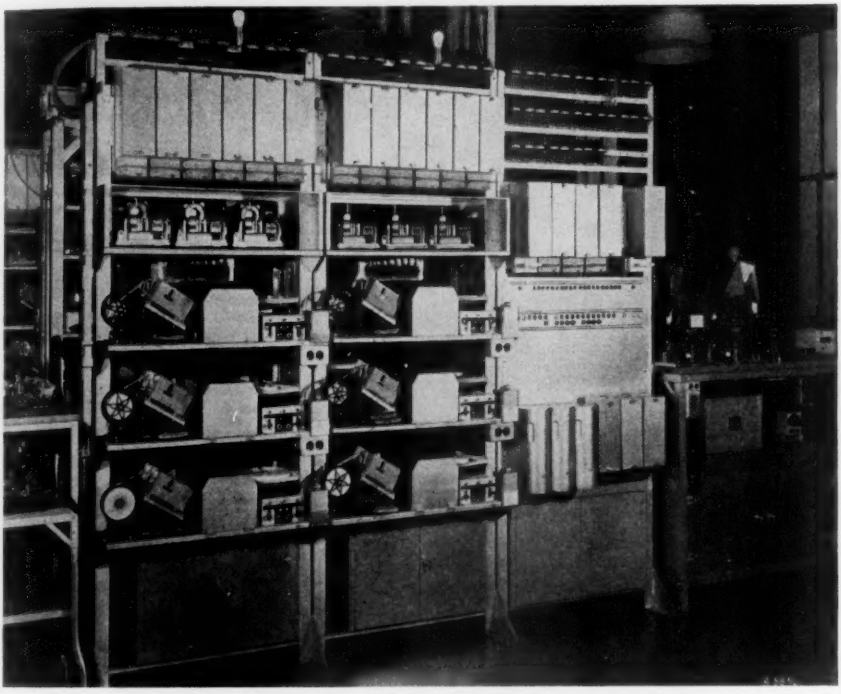


FIG. 3. Varioplex Set.

Figure 5 is a photograph of a Telefax transmitter of the slot deposit type. The patron presses the button, and places the prepared message in the slot. The message is automatically wrapped around the drum, the transmission takes place, and then the message is stripped from the drum and dropped into the receptacle at the bottom.

In 1917, Western Union became interested in carrier telegraphy, which was then called "an alternating-current system of telegraphy." However, it was not until 1927, after vacuum tubes became available, that the first practical system was ready. The advantages of carrier systems are many—to name them all would be to repeat common knowledge. Stated simply, it is possible to derive more telegraph channels from a given number of wires, and these channels are superior

to those obtainable from direct current systems of the grounded wire type. These improvements are the result of several factors, an important one being the use of paired wires. Carrier circuits remain susceptible to physical damage to the wire lines, and in fact require a higher type of maintenance, but the electrical performance of the system is much superior. The use of transposition systems and the

FIG. 4. Teletax Transmitter-Receiver.

use of balanced input to the equipment were contributory improvements, resulting in a large reduction of the interference picked up by the line.

Advances in equipment performance kept pace with developing transmission possibilities, and in 1937, Western Union's frequency-modulated telegraph carrier system was placed in operation. A frequency-modulated system provides a telegraph channel less subject to interference effects because of the FM-noise improvement, and it also eliminates telegraphic distortion formerly caused by attenuation vari-

ations in the lines. By FM telegraph carrier methods, the quality of signal transmission has been improved to the point where it is possible to transmit over circuits several thousand miles in length without the necessity of using regenerative telegraph repeaters at the points of interconnection.

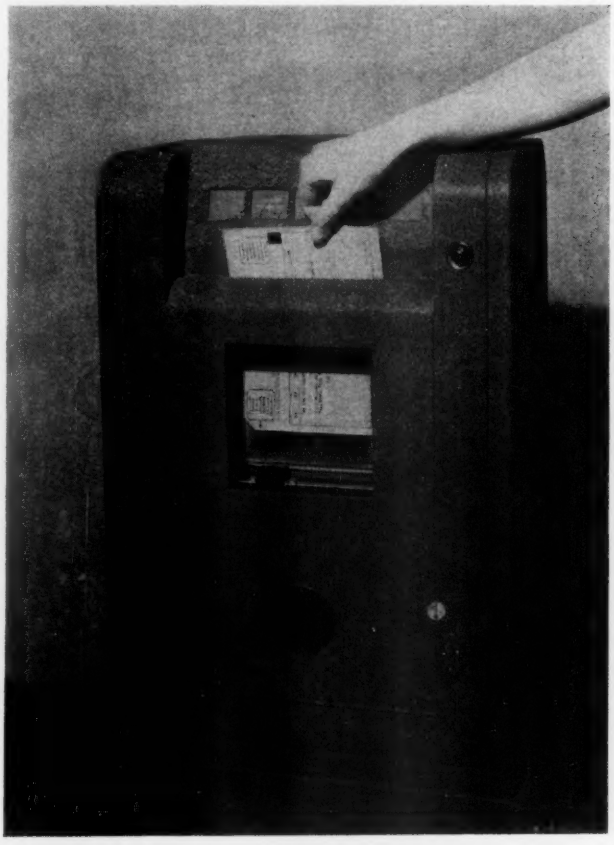


FIG. 5. Slot Deposit Telefax.

Figure 6 is a chart showing teleprinter and Multiplex signals for the letters R, W and A, chosen at random for illustrative purposes. It should be noted that the maximum line frequency (23 cycles for the teleprinter and 75 cycles for the Multiplex), shows up in the letter R. In the other letters, lower frequencies appear. The bottom half of the chart shows a typical telegraph spectrum analysis. Because the signals are square waves, no harmonic energy is produced at the even harmonics. In a workable system it is necessary to transmit a frequency spectrum extending from the lowest frequency component to a value at least equal to 1.7 times the highest "line frequency" impressed upon it.

This statement should not be interpreted to refer to the frequency spectrum required to transmit side band energy produced by modulation methods.

Figure 7 is a chart showing the method used for dividing voice bands, similar in frequency response to a telephone circuit, into telegraph carrier channels. Any voice band may be filled with a choice of three different types of telegraph carrier channels, or it may be used for Tele-

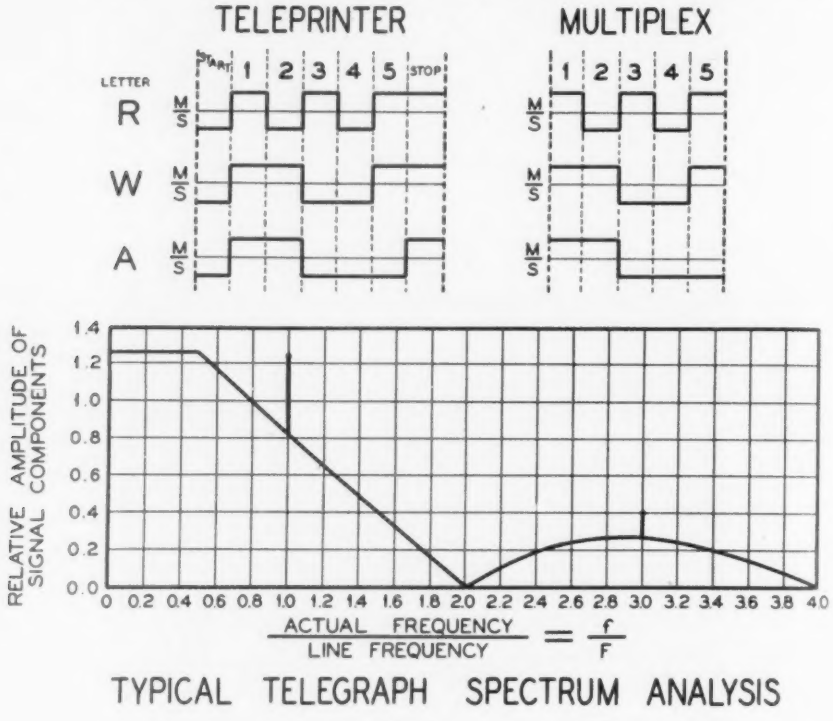
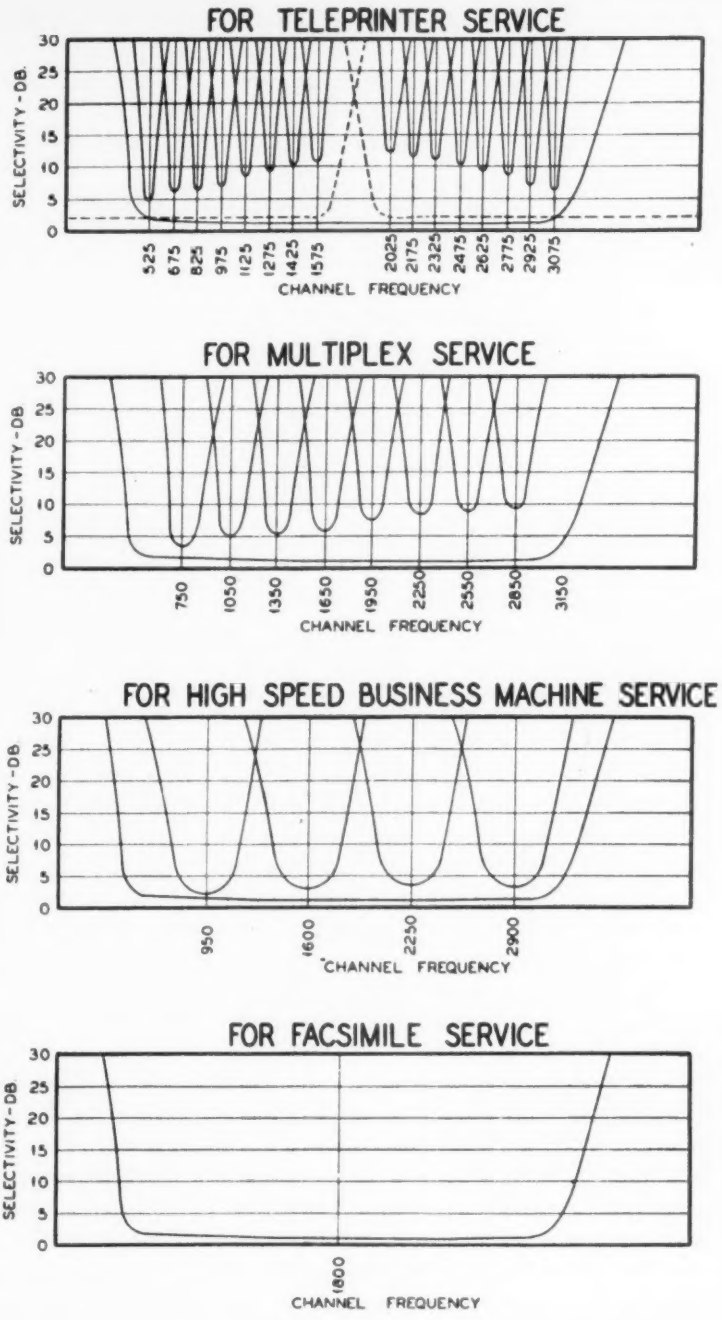


FIG. 6.

fax service, or as a telephone circuit. The teleprinter channels are spaced 150 cycles and make use of center frequencies ranging from 525 cycles to 1,575 cycles in the basic group. A similar group is translated to a higher position within the voice band by heterodyning the group against a frequency of 3,600 cycles. This avoids the design of additional equipment. All of these narrow carrier channels are deviated plus and minus 35 cycles by the telegraphic signals. Sixteen independent teleprinter systems may be operated in a single voice band.

Eight Multiplex or Varioplex circuits may be obtained from one voice band. These wide carrier channels are spaced 300 cycles and make use of center frequencies ranging from 750 cycles to 2,850 cycles, which are deviated plus and minus 70 cycles. These channels are also used for high-speed ticker interconnection.



APPARATUS: CARRIER — VOICE FREQUENCY BAND DIVIDED FOR TELEPRINTER MULTIPLEX BUSINESS MACHINE AND FACSIMILE SERVICES.

FIG. 7. Voice Band Subdivision.

Four channels suitable for interconnection of business machines may be obtained from a voice band. These channels will be spaced 650 cycles apart and the center frequencies will be 950, 1,600, 2,250 and 2,900 cycles.

The facsimile and telephone circuits require an entire voice band, or approximately 2,600 cycles of spectrum.

Figure 8. A pair of wires arranged for carrier operation will provide a total frequency spectrum of 30,000 cycles, and in standard Western Union practice, the G-1 Carrier System is used to sub-divide this wide

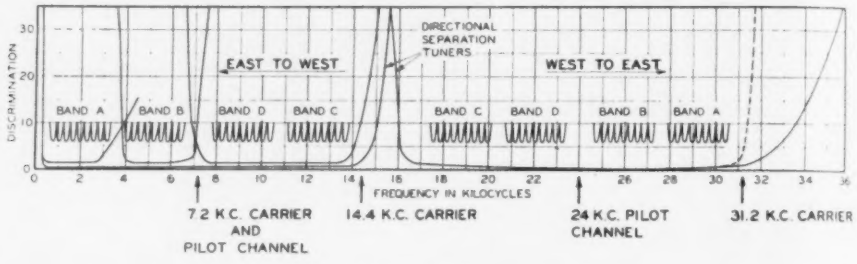


FIG. 8. G-1 Carrier System.

band into voice bands, which are connected to the appropriate carrier terminals. The G system is arranged for two-wire operation; hence it must have directional separation tuners. If arranged for four-wire operation, as would be the case with a radio circuit, these tuners are eliminated. When arranged for wire line operation, a G system provides four two-way voice bands—when arranged for radio operation, it will provide eight two-way voice bands.

Figure 9 is a photograph of a typical carrier installation in a Western Union office. Only the channel terminals are pictured, and these are of the type which are suitable for Multiplex operation. One voice band is required to supply the left-hand group and another to supply the right-hand group. The voice-band patching and monitoring switchboard is located at the end of the aisle. The equipment is all accessible from the front side; therefore additional carrier terminals can be located on the opposite sides of the steel supporting members. The translation equipment supplying these two voice bands is located in another part of the room.

It has been with some hesitation that so much wire line information has been included in a paper on radio relay operation, but it is hoped that such a procedure will give a better understanding of the requirements to be met when radio is applied to the modern telegraph plant. The subject of carrier telegraphy has been outlined in somewhat greater detail than other parts because the designs employed on wire lines are the basis for more elaborate systems which are to be employed on radio systems.

In 1920, Western Union began investigations leading to the possible commercial use of radio in the handling of telegrams. The Company interest increased during the years when short-wave long-distance radio transmission became a reality, and, in 1925, the Water Mill Laboratory was built on Long Island, about a hundred miles from New York City.

FIG. 9. Typical Carrier Installation.

This electronic laboratory was completely equipped with the most modern apparatus, and staffed by competent engineers, so that the latest technical advances could be evaluated in terms of the practical results being achieved in the radio field.

Notwithstanding rapid developments, the domestic telegraph industry, represented by Western Union, has never made commercial use of radio transmission, except for emergency purposes when wire lines were interrupted. This policy was maintained until 1940, because no radio system had been visualized which could compare with a pair of copper wires between two points on an overland route. Radio trans-

mission was considered most useful for broadcast dissemination and for mobile services, and had become widely used for intercontinental transmission. While ultra short-wave developments in the early 1940's seemed most promising, prior to this time it could not be said that radio was as economical as a wire line or that it could provide the necessary degree of circuit stability and continuity of operation. Another factor in this situation was the frequency shortage which existed. The number of channels which would be required to transmit the intercity trunk load of Western Union (950,000,000 messages annually) would be quite impossible to secure by allocation from the FCC because of the demands of many other necessary services, for some of which the use of radio is unavoidable.

In 1944, the situation was very different. At this time, as a result of more than four years of intensive war research, it became apparent that the application of super-high-frequency radio to telegraph transmission was not only feasible, but very practical. The progress made by hundreds of scientists working on radar and communication systems, the perfection of micro-wave techniques including wave guides and cavities, the development of new tubes such as the resonant cavity magnetron and the Klystron, and contributory effort in allied fields, all gave tremendous impetus to the growth of the new art. This new era is characterized by a change in terminology—the "old timer" feels himself lost in a sea of unfamiliar expressions and nicknames for new devices.

There is much fascination associated with microwaves, and one is tempted to dwell on the new developments to the neglect of the more practical aspects—the mechanisms by which these waves may be made to render service in a radio communication system. Today, the useful frequencies have been pushed higher by a factor of 100, and a frequency of 30,000 megacycles can be controlled by the radio engineer with almost complete knowledge of behavior. At such a frequency the wavelength is only 1 centimeter long, which approaches the wavelength of infra-red radiations. The waves are just like ordinary radio waves, except for the shortness of wavelength, and are the same kind of vibrations as those of light. Therefore, it is possible to work with microwaves in the same manner as with light, if proper dimensional allowances are made. There are no discontinuities to be expected insofar as the equipment is concerned as the wavelength is shortened.

It may not be obvious that the small size of the wave is such a valuable asset, but it is this property which permits the use of highly directive antennas, some of which make use of wave guides and horns, and others dipoles and parabolic reflectors. By combining the known techniques, a microwave beam of almost any desired shape and sharpness may be produced and projected to the distant point where a similar antenna is used to gather energy from only one direction. This ability

to concentrate energy results in tremendous saving of power. For instance, with antennas only four feet in diameter, a power gain of 30 decibels may be realized, and 1 watt will be as effective as 1,000 kilowatts in a non-directional system. Such high directivity is also useful in preventing interference. Furthermore, the same frequency can be utilized for transmission or reception as many as eight times at one location, or once for every 45° of azimuth angle. The perfection of a wave guide of special configuration which is known as a radio frequency hybrid permits the use of a single antenna for both transmission and reception if the frequency separation is in the order of 100 megacycles, or even on the same frequency if the application does not require too high an amplification in the receiver. And if it is desired to direct transmission to a moving object, a ship or an aircraft, this can be done with great facility, at the same time securing a certain amount of secrecy in the transmission.

Another property of microwaves is that they are propagated in the troposphere in accordance with optical laws. They penetrate into and perhaps through the ionosphere and are not reflected by it. Hence, microwaves are not useful for long-distance transmission, and in this particular they differ from ordinary short waves. Because microwave transmission does not depend upon reflection from the ionosphere, variations in the ionic density of the various layers of this medium have no effect upon transmission. It is not necessary to choose different frequencies for day or night operation, or for some particular distance. What a benefit it is to be free from the devastating effects of sun spots and to be divorced from such a fickle medium as the ionosphere! Ample proof of this beneficial circumstance was obtained recently when a severe disturbance of short wave radio and grounded wire communication resulted from unusual sun-spot activity, while the microwave system continued to function normally.

Microwaves travel in straight lines, except for some bending due to atmospheric density effects. Therefore, these waves do not follow the curvature of the earth, but disappear into space where they create no harmful interference. At first, this might seem to be a disadvantage, since the distance range is limited to relatively short distances, but the ability to use the same frequency assignment again and again in areas separated by approximately a hundred miles is a most fortunate circumstance. How else could the frequency shortage problem be met, if radio continues to expand at the present rate?

Before the war, practical use had been made of frequencies as high as 300 megacycles, but higher frequencies were still in the laboratory, waiting for the production of larger amounts of power, means of modulating the available power, and a method of receiving and demodulating energy at the higher frequencies. And how could currents be confined and made useful where they were wanted? Wires could not be used

because the energy would leave them, and the losses of coaxial cables were too high. All of these difficulties were overcome. Now, several hundred watts of microwave power are available. The tubes which generate this power may be amplitude or frequency modulated, and the higher the frequency, the easier it is to obtain a given frequency deviation with the required linearity. At a carrier frequency of 4,000 megacycles, a deviation of about one megacycle results when the potential on one electrode of the oscillator tube is varied by one volt. The use of polyethelyne brought adequate improvement in the dielectric properties of coaxial cables, in fact, solid filling of the cable is generally employed, which avoids the production of standing waves due to impedance irregularities. Wave guides and cavities are indispensable in confining the energy and delivering it to the desired portion of the equipment without excessive losses. And who could have predicted that the lowly crystal detector, of the type many of us used to listen to our first broadcasts, would turn out to be the only satisfactory microwave detector! Even television development lent a helping hand by furnishing the design of high-gain broad-band amplifiers, and pulsing techniques.

Another inducement is the enormous size of the microwave spectrum available for exploitation. We now have more than 100 times the frequency band width previously available, and therefore it is possible to consider the assignment of reasonably large signalling spectrum to each radio channel. If properly allocated, the necessarily large number of telegraph channels can be provided, and the door is opened to the development of wide band systems which are economically attractive as compared to a wire line, or a coaxial cable with repeaters. Radio relaying holds great promise as a means of network broadcasting of television programs.

At microwave frequencies, atmospherics do not exist, and any radio interference must come from a local and not a distant source. A very simple portable direction finder is all that is required to discover the location of an interfering signal.

There are several additional advantages of a microwave relay system as compared to a wire line. The initial cost and the annual expense of operation are believed to be less, if a large number of telegraph channels are derived from the radio system. The quality of transmission is improved. Very little time is required to install new equipment, or relocate an existing system, and if a change in plan is necessary, most of the equipment is salvageable. Maintenance operations are concentrated at a few relay points instead of being distributed along the line. The loss of time due to physical damage to the equipment resulting from storms will undoubtedly be less. Construction difficulties over bodies of water, mountains, deserts, and in jungles are reduced. And finally, there is a tremendous reserve of circuit capacity, which

can accommodate new services because of the cheapness of band width, and which can provide for 100 per cent. alternate route or fallback protection in the event that a direct circuit between two cities is interrupted.

These advantages, coupled with favorable results from economic studies, led to the inescapable conclusion that Western Union should undertake a comprehensive experimental program, pioneering in the commerical use of microwaves for telegraph purposes. Accordingly, in July, 1944, a patent license agreement was entered into with the Radio Corporation of America for the use of the necessary circuit and system patents. This agreement is not restrictive to record communication applications, but also provides for the relaying of sound and television program material. Recently, another agreement between Major Edwin H. Armstrong and Western Union makes the commercial use of the Armstrong frequency modulation patents available to the Telegraph Company.

In August, 1944, applications for construction permit were filed with the Federal Communications Commission to build an experimental radio relay system connecting New York and Philadelphia.

In September and October, 1944, the Commission held a hearing in the matter of allocations of frequencies to the various classes of non-governmental services in the radio spectrum extending to 30,000 mc. At this time, Western Union submitted a statement apprising the Commission of its plan to employ microwaves. This plan included an evaluation of the Western Union proposals from the viewpoint of public need and benefit, and technical information relating to relay operation. The Company was highly encouraged because of the consideration given to the needs of radio relay operation by the Commission in its final report, dated May 25, 1946, allocating the following frequencies to non-government fixed and mobile services, which may be used for experimental radio relay operation:

1,760– 2,100 mc.
2,450– 2,700 mc.
3,900– 4,400 mc.
5,650– 7,050 mc.
10,500–13,000 mc.
16,000–18,000 mc.
26,000–30,000 mc.

The New York-Philadelphia system was placed in operation in March, 1945, under RCA experimental licenses, and continuous observations have been made since this date. A frequency near 4,000 megacycles has been the only frequency employed because during the war and subsequently only a limited amount of equipment and a few engineers were available, and because this frequency band seemed to be the most promising of the several which had been allocated.

Installation of the final radio equipment is scheduled for April of 1946. At this time the hastily assembled test equipment will be removed, and experimental transmission of telegrams will be initiated, under Western Union licenses, and utilizing the latest models of factory-produced radio equipment.

For the first phase of experimental operation, existing types of wire line voice-band translation equipment and carrier terminals will be utilized to transmit commerical telegrams. The Type G voice-band translation equipment rearranged for 4-wire operation, and thus supplying 8 voice bands, will be manufactured by the Federal Telephone & Radio Corporation. The telegraph channel terminals will be manufactured by the Philco Corporation. Western Union specifications are being followed by these two firms in the production of the equipment.

Within a short time simultaneous propagation tests will be carried out between New York and Neshanic, N. J., in four frequency bands; namely, 2,000, 4,000, 6,000, and 11,000 mc.

In an operation of this magnitude, all divisions and departments of the Company have been active in one way or another. The following paragraphs will include the general scope of this activity, but the details are considered to be beyond the scope of this paper.

Western Union engineers have undertaken the development and design of new voice-band translation equipment which is necessary to adapt radio operation to telegraph use. This work is progressing in the Western Union laboratories at the present time. It is understood that the design details of this new system will be presented in a forthcoming paper; consequently, only a general description will be included herein.

The rearrangement in office layout required for the accommodation of increased amounts of carrier terminal and voice-band translation equipment is another problem which has required a large amount of engineering planning.

Western Union engineers have also been responsible for the design of steel towers which will be used at all of the relay points, for the buildings which will be used at each of the relay stations and at some of the terminals, and for the design of the emergency power equipment which will be used at relay stations.

The Plant Department has been responsible for the preparation of trial profiles from which the station sites were located. This group has also arranged for obtaining space in high city buildings suitable for the installation of the terminal radio equipment, and for the purchase of land upon which the repeater stations are being built. The Plant Department is also responsible for construction activities. The Plant Engineer has contributed to the overall planning, especially in the preparation of cost estimates.

The Traffic Department has been responsible for the assignment of the carrier circuits which will be derived from the various radio systems. This department also selects the number of teleprinter channels, the number of Multiplex channels, and the number of Telefax channels which will be operated between any two functional offices. Not all of the available telegraph channels will be permanently assigned—at least 50 per cent. will be held in reserve for emergencies, and to provide alternate routes in the event of a circuit interruption.

The Eye Bank for Sight Restoration, Inc., 210 East 64 St., N. Y. C.—Names of seventy-five leaders in the fields of science, finance and business who will serve as members of a council in sponsoring the work of The Eye-Bank for Sight Restoration, Inc., were announced today by Mrs. Henry Breckinridge, Executive Director of that organization.

The Council, headed by Albert G. Milbank, prominent lawyer and foundation president, will aid in the plan to establish a nationwide eye bank for obtaining and making available healthy corneal tissue to restore the vision of persons whose sight has been lost through affection of the cornea. The plan which the Council is sponsoring includes research, study and instruction of ophthalmologists in the delicate surgery required in performing the corneal graft operation.

Fellowships which will enable advanced study in causes of corneal affections, and in methods to increase the time which corneal tissue may be preserved and made available for use in sight restoration operations are, also included in the plan.

Similar to the function of blood banks in restoring exhausted blood supply, the Eye Bank was organized to make possible restoration of the sight of persons whose vision has been destroyed because of corneal affections by replacement with healthy tissue from the eyes of other persons. Of the 250,000 persons in the United States who are presently blind, it is estimated that the sight of five to seven per cent. has been lost through opaque corneas, and that the vision of approximately 10,000 of those so affected might be restored if healthy corneal tissue were available for the corneal graft operation.

It is the purpose of the Eye Bank to locate, obtain and have accessible wherever and whenever needed the all-important corneal tissue. This "capital stock" of the Eye Bank—more precious than gold—may be obtained only from persons whose sight requires the removal of an eye whose corneal tissue is unimpaired, or by obtaining the healthy eyes of persons immediately after death.

R. H. O.

SECONDARY ELECTRON EMISSION FROM OXIDE-COATED CATHODES.*

BY

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PART I.

ABSTRACT.

The secondary electron emission from alkaline-earth oxide-coated cathodes has been investigated under both continuous and pulsed bombardment. Various factors affecting the yield, such as dependence upon primary voltage, collecting voltage, temperature, time, and angle of incidence, are noted, and the present state of the theory is discussed. Experiments have been performed with three types of apparatus. Yield vs. Energy data reveal values of δ of 4–7 at room temperature, with a more or less flat maximum at approximately 1,000 volts primary energy. The yield increases with temperature in an exponential manner, and plots of log $\Delta\delta$ (i.e. $\delta_{K.^\circ} - \delta_{300^\circ K.}$) vs. $1/T$ give straight lines. Values of Q_1 between 0.9 – 1.5 eV. are generally indicated, and from extrapolation of these curves, yields exceeding 100 at 850° C. are deduced. The secondary emission depends upon the degree of activation, and increases with enhancement of the thermionic emission characteristics. Short-time effects such as growth or decay of secondary current after the onset of primary bombardment or persistence after the cessation of bombardment have not been observed, and values of yield obtained by pulsed methods are in accord with those obtained under D.C. conditions. Tail phenomena reported by J. B. Johnson and interpreted as "enhanced thermionic emission" from oxide-coated cathodes become manifest only under experimental conditions characterized by certain space-charge effects, and have been effectively simulated by bombarding a tantalum target adjacent to an electron-emitting tungsten filament. Various measurements of the energy distribution of secondary electrons as a function of primary voltage and temperature have been obtained. It was observed that the average energy of the secondary electrons decreases with temperature at a rate which more than compensates for the increase in the number of secondaries emitted per incident primary. The mechanism of the observed dependence of yield upon temperature is not well understood. Various alternative explanations are discussed and, in the light of the present state of our knowledge, regarded as untenable.

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I. INTRODUCTION.

Although secondary emission from solid bodies had previously been of interest both from the theoretical and experimental points of view, the paramount importance of this phenomenon in the operation of the magnetron [1] stimulated the demand for pertinent information regarding secondary-electron yields of oxide-coated cathodes.

Allied phenomena such as thermionic emission, electrical conductivity and photoelectric emission of the alkaline-earth oxides have been the subjects of extensive investigations. Measurements of the secondary emission at room temperature had been made by Sixtus [2] and by Ziegler [3] using triode arrangements, and by Bruining and de Boer.[4] Morgulis and Nagorsky [5] originally observed that the secondary emission from an oxide-coated target surface increases with temperature, and their measurements indicated yields as high as 14 secondaries per primary at 850° K. However, practically no information regarding the thermionic emission from their target cathodes was reported by any of these investigators and, indeed, the meager references in some instances are construed to indicate a degree of activation far inferior to that which is compatible with standards which subsequently have been attained.

It has been possible recently to obtain emissions in pulses of microsecond duration exceeding by factors of several hundred the values previously regarded as the maximum available under D.C. conditions. It was therefore of interest to study simultaneously both the secondary emission and thermionic emission characteristics of oxide-coated cathodes prepared under conditions whereby the physical-chemical state of the system requisite for copious pulsed thermionic emission is realized. A further object of this investigation was to ascertain whether the secondary emission available in short pulses is equal to that observed under steady state conditions.

II. GENERAL REMARKS.

A. Mechanisms of Secondary Emission.

The secondary electrons emitted by a material bombarded by a primary electron beam can be ascribed to three different mechanisms.

This classification is made on the basis of the energy distribution of the emitted electrons, which may readily be determined by the customary procedure using a retarding field. It is observed that there exists a distinguishable peak at the energy of the incident beam and these electrons are, of course, to be identified as elastically reflected primaries. At the other end of the spectrum one observes a group of slow electrons with a Maxwellian energy distribution. The average energy of these electrons is only a few volts when the primary energy is of the order of hundreds of volts. Between these slow electrons and the elastically reflected ones there is found a group of low intensity with energies extending up to the primary energy. The slow electrons arise from collisions between the primaries and the atomic electrons of the target, in which sufficient energy is transferred to the latter so that these emerge from the solid material. These electrons are, therefore, true secondaries.

In the measurements it is not difficult to separate the elastically reflected electrons from the remaining ones. While such a separation of secondaries and inelastically scattered primaries is impossible, in general, the former are usually much more intense than the latter and, for practical purposes, distinguishing between them is unnecessary. The separation is also unnecessary from the point of view of obtaining emission from a target regardless of the origin of the emitted electrons.

The secondary emission has been measured under a variety of conditions for a great number of substances and, in the case of some materials, the yield has been measured by several investigators. For certain pure metals which can be well outgassed, the results obtained agree very satisfactorily. However, the observations in the case of more complex materials, and for many metals as well, are quite discordant. In fact, in the case of Mg, for example, the results of different observers show differences of the same order as the comparison between two totally dissimilar substances. This serves to emphasize that secondary emission depends as much on the physical state of the material, and on small impurities, as on the gross chemical composition. Therefore, in specifying the capacity of a given material for secondary emission, it is essential to state the method of preparation and treatment. This is, of course, extremely pertinent in the case of oxide-coated cathodes.

B. Factors Affecting Secondary Emission.

Inasmuch as the current of secondary electrons is proportional to the primary current, it is customary to describe the secondary emission in terms of the ratio of secondary to primary currents.* This ratio will be referred to, for the sake of brevity, as the *yield*, sometimes designated as the production coefficient, symbolically δ. In this sec-

* Secondary current here includes electrons of all energies (positive collector voltage) and all directions of emission on the entrance side of the target.

tion, those factors affecting the magnitude of the yield are described briefly.

From the practical point of view, the most important factors governing the yield are, as was implied above, the physical (and chemical) nature of the emitting material. The questions involved here are rather complex, and the detailed discussion of this question is postponed to a later section. For the present, the dependence of the yield upon the following will be considered:

1. Primary voltage;
2. Collecting voltage;
3. Temperature of the emitter;
4. Time;
5. Angle of incidence.

1. *Dependence on Primary Voltage*

All known secondary emitters are observed to have the same qualitative dependence of the yield on primary energy. Starting at low voltages the yield rises smoothly until a maximum yield is attained, usually in the neighborhood of 400–600 volts. Thereafter the yield decreases slowly and, for very large energies, probably approaches a constant value. Curves showing the typical behavior appear in Fig. 4. Although, in a few cases, the energy at which the maximum occurs lies at voltages considerably above the range of values given, it is remarkable that in the great majority of cases the position of the maximum shows such little variation. In referring to the yield, the maximum value of δ shall be specified in the following discussion. In view of the above remarks, this will be a sufficient measure of the magnitude of the secondary emission. It may be added that the shape of the observed yield curves is readily understood in terms of the existing theory (Section II, C).

2. *Dependence Upon Collecting Voltage*

It has been observed that, in the case of metals, the secondary current is independent of the collecting voltage as long as this is positive. For substances with lower conductivity, on the contrary, an increase of yield with increasing collector voltage has been observed.[4] This effect may be qualitatively understood when it is recognized that, by virtue of a yield larger than unity, more electrons leave the emitter than enter. As a consequence of the high resistance of the oxide layer, a positive charge will appear on the outer surface of the layer and a negative charge on the inner surface. Thus a double layer is formed. The resulting field promotes a phenomenon analagous to cold emission. The dependence upon collector voltage arises from the fact that the

potential on the outer surface of the oxide layer is limited to values smaller than the collector potential. An increase in the latter is accompanied by an increase in the internal field.[6] It is evident that, in comparing results for target materials which show this effect, it is necessary to take into account possible differences in collector voltage.

3. *Dependence Upon Temperature*

Measurements of the yield have usually been made at room temperature. However, in the case of the alkaline earth oxides, the yield increases very rapidly with temperature. If the so-called "anomalous" yield, i.e. the differences between the yield at $T°$ K. and that at room temperature, is plotted logarithmically as a function of the reciprocal of the absolute temperature, a straight line is obtained so that the dependence upon temperature is of an exponential character. This is represented by the equation:

$$\Delta\delta = Ae^{-Q_1/2kT}. \tag{1}$$

4. *Dependence Upon Time*

Under certain conditions (Malter effect [6]) time may be involved in the growth and decay of secondary emission. This would obviously be important both theoretically and in the pulsed operation of the magnetron if characteristic of oxide-coated cathodes.

5. *Dependence Upon Angle of Incidence*

The values of the yield given here refer to normal incidence of the primary beam. For oblique incidence the yields are larger as may readily be understood from the fact that the secondary electrons are formed closer to the surface and are, consequently, absorbed to a lesser extent. For nearly grazing incidence the yield may be increased by a factor of as much as 3. The value of this factor depends somewhat on the primary voltage. It is also dependent on the chemical composition of the target. See Refs. 7 and 8.

C. Theoretical Considerations.

From the quantitative point of view, the only successful description of secondary emission is that due to Wooldridge.[9] Here, making assumptions, some of which may be open to question, the quantum mechanical treatment of the collision process between primary and atomic electrons in a pure metal is developed. These calculations supplemented by considerations of the absorption of the primaries and secondaries are capable of accounting for the observed shape of the yield vs. primary voltage curves. Since the shapes of the yield curves for substances other than metals are of the same form, the theory may be

"extrapolated" in its application. In fact, the application of the calculations to BaO affords as favorable a comparison between theory and experiment as is found for the metals. This property of the theory is not greatly surprising, since the shape of the yield curves depends essentially upon such properties of the emitter as are largely independent of its metallic or non-metallic nature. At low primary energies the observed increase is explained as a consequence of a smaller mean free path for the primaries than for the slower secondaries. With increasing energy, primaries are able to penetrate the material to greater depths, and an increase of yield ensues until the depth of primary penetration exceeds the average range of the secondaries. At larger energies the observed decrease of yield is accounted for by a decreased collision efficiency.

However, in the absence of a knowledge of atomic wave functions in the metal, the theory cannot make any quantitative predictions concerning the magnitude of the emission. In fact, this uncertainty of the theory is circumvented by regarding the parameter expressing the atomic binding, which enters as a scale factor, as an adjustable constant.

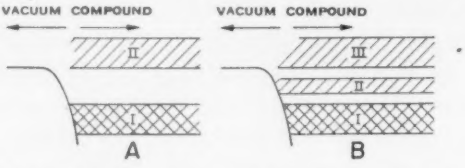

FIG. 1. Energy level diagram for substances (*A*) with high secondary yield and (*B*) with a smaller value of δ (Ref. 4). Case (*A*) is more favorable because a primary electron can lose energy only by causing transition of electrons from band I to II from which electrons have a high probability of escaping. Because band I is normally completely occupied, electrons from band II cannot easily return to the lower band. In the second case, primary electrons lose energy by causing transitions from I to II from which electrons cannot escape. To leave the substance they must be raised to band III, from which they can also easily return to band II. Whether or not a given material is of type (*A*) or (*B*) can be determined by a comparison of the absorption spectrum with the red limit of the internal photoelectric effect.

It seems that at present one may attempt only qualitative descriptions of secondary emission so far as its magnitude is concerned. Such a description should take into account the number and disposition of normally unoccupied energy bands of the material, and the effect on the energy scheme of the addition of impurity atoms. In general, greater emission is to be expected if there exists an empty band in such a position that electrons excited into this band may leave the metal without requiring additional energy. If there are no excited states between the levels of this band and the normally occupied levels, the situation for emission is more favorable. The significance of these remarks is illustrated by the comparison between the two level schemes illustrated in Fig. 1.

The secondary emission also depends on all surface conditions which affect the work function, and a lowering of the work function will, cet. par., increase the emission. Obviously, this makes the sensitivity of secondary emission to contaminating influences, etc., more understandable.[9]

Such remarks apply to the emission at a given temperature. It has been previously mentioned that in the case of metals the temperature does not influence secondary emission. This result may be attributed to the fact that for the temperature changes involved the thermal excitation energy of the order of 0.1 volt is, in general, insufficient to excite tightly bound electrons.

D. Extrapolation of Measurements to Higher Temperatures.

Due to technical considerations (space charge effects, etc.) it is impossible to measure the yield at target cathode temperatures at which thermionic emission becomes copious. In order to obtain values of δ at normal oxide-coated cathode operating temperatures (850° C.) it is consequently necessary to extrapolate data observed at lower temperatures. This procedure is justified if the work function does not vary appreciably with temperature, and if the physical characteristics of the system are not appreciably altered, i.e. if increase of temperature does not promote any process whereby the concentration of the essential metallic component is decreased.

Experimental evidence in this regard has been obtained by Morgulis and Nagorsky,[5] and Huxford.[10] The former have measured the total photoelectric emission J_φ from an oxide-coated cathode. This is represented by the equation:

$$J_\varphi = BT_1^n \exp. \frac{-e\varphi}{kT_1} \qquad (2)$$

$$n \approx 2 \ ,$$

from which φ can be calculated. The logs of J_φ/T_1^2, plotted against $1/T_1$, yield a straight line, the slope of which is φ. The value thus obtained agreed satisfactorily with that evaluated from the thermionic emission using Richardson's equation. Huxford found that φ computed from the long-wave limit of the photoelectric effect

$$(\varphi = hc/e\lambda_0) \qquad (3)$$

agreed with that obtained from the Richardson plot.

These experiments are cited in a more or less uncritical manner to indicate that, in any event, the assumption is not invalidated by existing evidence, but is rather in accord with the limited data available.

III. EXPERIMENTAL DETAILS AND RESULTS: D.C. EXPERIMENTS.

A. Description of Apparatus.

1. *Beam Tube*

The principles involved in measuring secondary electron emission are most conveniently described in terms of the actual experimental arrangement. Fig. 2 is a schematic diagram of a more or less standard system for producing a bombarding beam of electrons, and collecting the secondaries emitted by the target. The secondary electron collector

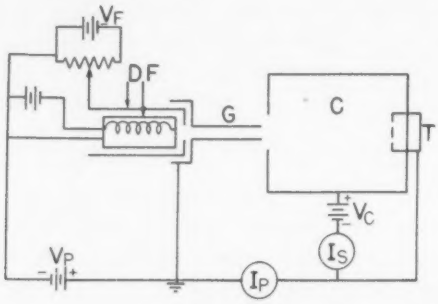

FIG. 2. Schematic diagram of the experimental arrangement for measuring secondary electron emission.

C and the electron-gun assembly are mounted on glass supports protruding from a ground joint containing six tungsten-glass seals. The electron-gun assembly consists of the gun *G* (which is a tube 14 mm. long and 1.5 mm. in diameter fastened into a cap), the cylinder *D* and the source of electrons *F*, which may either be a tungsten filament or an oxide-coated cathode. The cathode is mounted on a removable grind to facilitate replacement without disturbing the other elements. Focusing is accomplished by adjusting the potential of *D*. The target *T* is a nickel can containing a spiral tungsten filament for heating it. By means of the sylphon arrangement, the target is moved out of the path of the electron beam to permit observation of the beam on the fluorescent screen *S*. In order to facilitate visual alignment of the various elements, the screen may be moved out of the path by means of the electro-magnet *M*, which is slid along the tube over the iron rod *I*. The target is adjusted by moving it into the path of the beam until the fluorescent spot completely disappears.

The metal parts, which are all nickel, could be carefully outgassed by induction heating to approximately 1000° C. The target was degassed by electron bombardment from its heating filament. Pressures lower than 10^{-6} mm. of Hg were measured with an ionization manometer during the experiments.

The calibrations of target temperature as a function of the power dissipated in its heater filament were carried out in a special supplementary tube. The equilibrium temperature of the target at different

values of heater power was measured with a nickel-tungsten thermocouple consisting of .002″ wires spot-welded to the same target used in the secondary emission measurements. The thermocouple was standardized in an independent experiment. The shape of the heater-power vs. temperature curve thus obtained was in accord with theoretical expectations. Optical pyrometer measurements at higher temperatures were also in satisfactory agreement with the thermocouple data.

In order to test the operation of the apparatus, and the reliability of the data obtainable with it, the production of secondary electrons by primary electrons impinging upon a well-degassed nickel target was investigated. Fig. 4 contains a plot of the results as compared with data obtained by other investigators.

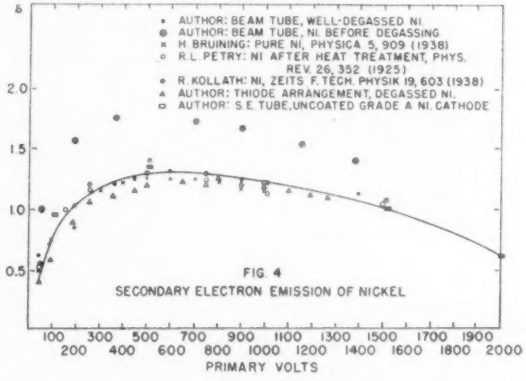
AUTHOR: BEAM TUBE, WELL-DEGASSED NI.
AUTHOR: BEAM TUBE, NI. BEFORE DEGASSING
H. BRUINING: PURE NI, PHYSICA 5, 909 (1938)
R.L. PETRY: NI AFTER HEAT TREATMENT, PHYS. REV. 26, 352 (1925)
R. KOLLATH: NI, ZEITS. F. TECH. PHYSIK 19, 603 (1938)
AUTHOR: THIODE ARRANGEMENT, DEGASSED NI.
AUTHOR: S.E. TUBE, UNCOATED GRADE A NI. CATHODE
δ
2.0
1.5
1.0
0.5
FIG. 4
SECONDARY ELECTRON EMISSION OF NICKEL
100 200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500 1600 1700 1800 1900 2000
PRIMARY VOLTS

FIG. 4. Secondary electron emission of nickel. ● Author: Beam tube, well-degassed Ni. ⓪ Author: Beam tube, Ni, before degassing. × H. Bruining: Pure Ni, *Physica*, **5**, 909 (1938). ○ R. L. Petry: "Ni after Heat Treatment," *Phys. Rev.*, **26**, 352 (1925). ⊙ R. Kollath: Ni, *Zeits f. Tech. Physik*, **19**, 603 (1938). △ Author: Triode arrangement, degassed Ni. □ Author: S.E. tube, uncoated Grade A Ni, cathode.

2. *S.E. Tube*

In accordance with the objective, as stated in the introduction, of studying simultaneously both the thermionic and secondary emission properties of standard magnetron cathodes under standard conditions, a special tube which could be sealed-off from the vacuum system after processing was developed. Various tests of the electron optics, etc., were made on a large cylindrical glass experimental jar containing appropriately placed grinds, pumped by a high speed metal fractionating pump. This specialized type of tube, designated as the *S.E. Tube*, is shown in Fig. 5. The specimen target cathode T is mounted at the end of two tungsten rods R which slide through glass sleeves S supported by glass pillars Q from the press P. Electrical connection between the other ends of the supporting rods and the two leads in the Kovar-glass press is effected by means of a specially-treated extremely flexible copper

braid B, coiled loosely around the pillars Q. Both heater leads of the cathode T are brought out at one end. By tilting the tube, the target T may be shifted from position (1) under the secondary emission measuring electrodes to position (2) inside the Kovar cup K. The latter may be immersed in water to prevent excessive heating during the drawing of high pulsed emission performed while it occupies position (2).

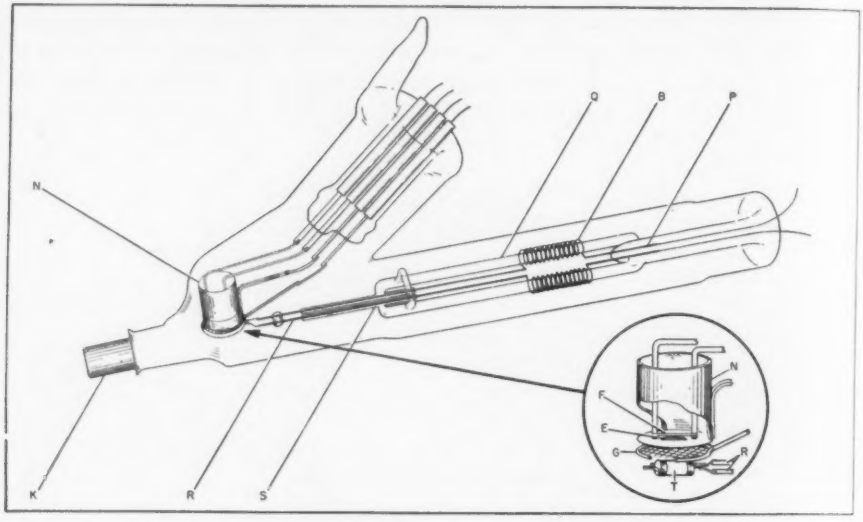

FIG. 5. Drawing of an S.E. tube. T is the target cathode, which can be slid by tilting the tube from position (1) under the secondary emission—measuring electrodes to position (2) inside the Kovar Cup for diode operation. Filament F mounted adjacent to slit E in Ni can N constitutes the electron gun. Grid G collects secondary electrons emitted by target T under bombardment from the gun assembly.

The secondary emission measuring-assembly consists of a straight tungsten filament F mounted to one side of a 1 mm. $\times$ 5 mm. slit E in the closed lower end of the nickel can N, in such a manner that the surface for which δ is measured cannot directly see the filament. This avoids the possibility of contamination of the surface due to the evaporation of tungsten from the electron gun filament. The coarse grid G serves as the secondary electron collector. By adjusting the potential between the source of primary electrons F and the can N, a linear beam is focused on the target cathode, T. Essentially, the secondary emission is measured by making T positive with respect to F, G positive with respect to T, and observing the primary and secondary currents taking into account the correction due to the fact that G intercepts a small portion of the primary electron beam.

In general, the effect upon the accuracy of the measurement of δ due to primaries directly intercepted by the collector grid (which is positive with respect to the anode) in a triode arrangement in which secondary

emission from the anode is being measured may readily be seen as follows:

Let j_k represent the cathode emission current, j_g the grid current, and j_a the anode current. If α is the fraction of the cathode current interrupted by the collector, the total current reaching the target and releasing secondaries is equal to $(1 - \alpha)j_k$. If j_s represents the secondary emission from the anode, the following relationships apply:

$$j_s = \delta(1 - \alpha)j_k, \tag{4}$$

$$j_a = (1 - \alpha)j_k - j_s, \tag{5}$$

$$j_g = \alpha j_k + j_s, \tag{6}$$

$$j_k = j_g + j_a. \tag{7}$$

From equations (4), (5), and (7)

$$\delta = 1 - \frac{j_a}{(1 - \alpha)(j_g + j_a)}. \tag{8}$$

Thus, for small values of α, the correction is relatively unimportant. Although this was the situation in the case of S.E. tubes, due to the geometrical disposition of the electrodes, the correction was always nevertheless readily available experimentally.

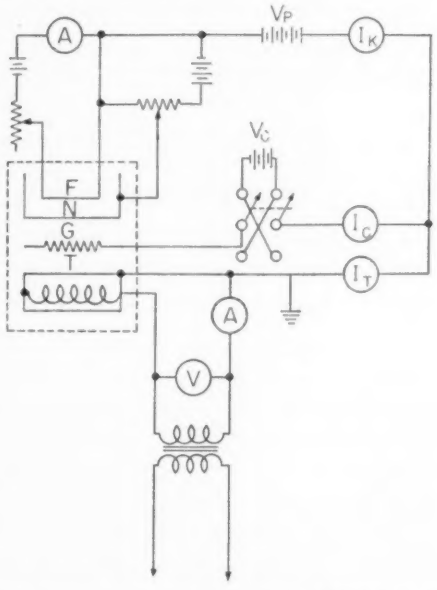

FIG. 6. Circuit diagram showing the essential details of the method of measuring secondary electron emission using S.E. Tubes.

The essential elements of the electrical circuit used in the present experiments are shown in Fig. 6. The following equations relate the

various measured currents:

$$i_s = I_s' + i_{th} + i_{gc}, \tag{9}$$

$$i_p = I_p' + i_{gc}, \tag{10}$$

$$i_T = I_p' - I_s' - I_{th}, \tag{11}$$

where:

I_s' = true secondary current,
I_p' = true primary current,
i_{th} = thermionic emission from target = $i_T(V_G^+, V_F^\circ)$ [the current through meter i_T with the collector electrode G at a positive potential with respect to the target T (ground), and gun electrode F at zero potential with respect to the target, T] and $i_c(V_G^+, V_F^\circ)$,
i_{gc} = electron beam current directly collected by the collector grid * = $i_c(V_G^-, V_F^-)$,
$i_p = i_k(V_G^\pm, V_F^-)$,
$i_s = i_c(V_G^+, V_F^-)$.

One of the several equations yielding a value of δ is obtained by combining Eqs. 9 and 10:

$$\delta = \frac{I_s'}{I_p'} = \frac{i_s - i_{th} - i_{gc}}{i_p - i_{gc}}. \tag{12}$$

Similarly, other combinations of meter readings furnish values of the yield, thereby affording checks upon the consistency of the experimental data.

It is assumed that the value of grid-collected current, $i_{gc} = i_c(V_G^-, V_F^-)$, applies for V_G^+. This is justified when $\frac{V_F + V_G}{V_F} \approx 1$, as indicated by the fact that, experimentally, $i_k(V_G^-, V_F^-) \approx i_k(V_G^+, V_F^-)$.

The S.E. tubes are subjected to a preprocessing treatment prior to the mounting of target cathodes. The schedule consists essentially of the following operations:

1. Electrolytic polishing of metal parts;
2. Sealing together of tube with .010″ spiral tungsten filament replacing target cathode T;
3. Sealing on vacuum system, and baking tube at 450° C. with $\frac{3}{4}$ atmosphere of hydrogen;
4. Evacuation, and one-hour bake at 450° C.;
5. Degassing of Kovar cup by heating to redness for one-half hour by electron bombardment from filament T;
6. Degassing of metal parts N and G by electron bombardment from F;
7. Sealing off to await mounting of target cathode.

* Elastically reflected primaries are also included in this term.

The principal steps in final processing schedule subsequent to mounting the target cathode and leaving it in position (2) inside the Kovar cup include the following:

1. 450° C. vacuum bake for one hour;
2. Degassing of metal parts N and G by electron bombardment from filament F;
3. Cathode conversion and activation according to accepted standard procedure generally consisting of:
   a. Slow heating of cathode to approximately 700° C.;
   b. One hour binder breakdown and cathode degassing at 700° C.;
   c. Rapid conversion of carbonates to oxides at 1000° C.;
   d. Drawing D.C. emission of gradually increasing magnitude;
   e. Pulsing of cathode at about 10 amps./cm.^{2};
4. Repeat 2;
5. Rebake tube and vacuum system, 300° C., with cathode initially at 800° C.

Pressures of the order of 5×10^{-8} mm. of Hg are measured at seal-off.

The fluorescence of the target cathode makes it possible to observe the bombarding beam, and the focusing action of the electron-optical system.

The temperature as a function of heater power was calibrated in special sealed-off tubes with several standard target cathodes. Thermocouples consisting of .002" Ni-W wire, were spot-welded to the surface. Lead wires from the cathodes were of various length, to introduce thermal conductivity differences exceeding those encountered from tube to tube because of slight variations in construction. The agreement among these experiments, and the consistency with optical pyrometer measurements, was entirely satisfactory.

B. Results.

1. *Yield vs. Energy*

The nature of the variation of secondary yield with bombarding energy is practically the same for all substances. At room temperature δ generally attains a more or less flat maximum value in the range between 4–7 at approximately 1,000 volts primary energy, for a well-activated BaSr oxide-coated cathode. The dependence upon degree of activation will be discussed in a subsequent sub-section III, B, 3.

Figure 7 is a plot of secondary yield as a function of primary energy for several typical magnetron cathodes, the measurements extending to V_p = 1,200 volts. Fig. 8 shows data obtained at somewhat higher primary energies. In accord with theoretical expectations, it is seen that the general shape of the curve is not radically altered by elevating the temperature of the target, although the absolute values of the yield are increased. Table I lists results obtained by other investigators.

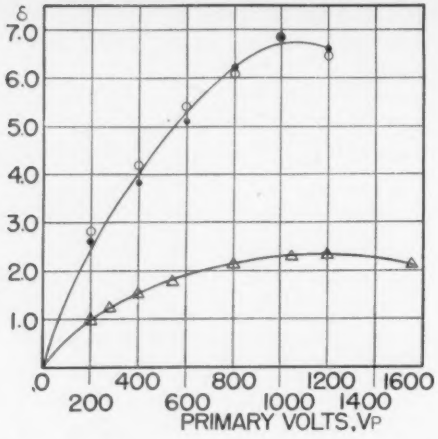

FIG. 7. Secondary electron yield, δ, as a function of primary energy, V_p, for several typical oxide-coated cathodes. The target in Spec. S.E. 2 was in a poor state of activation. ● S.E. 5. △ Spec. S.E. 2. ○ S.E. 1.

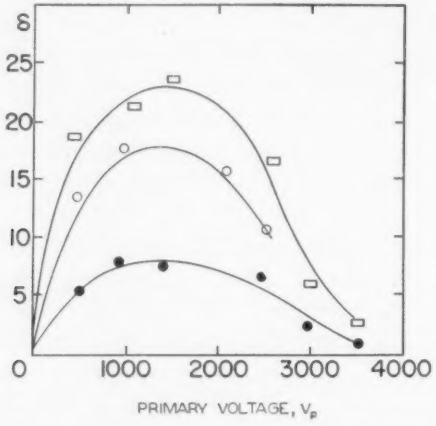

FIG. 8. Secondary electron yield, δ, as a function of primary energy, V_p, for an oxide-coated cathode at different temperatures. Tube S.E. 13. ● Room temperature. ○ 615° C. □ 660° C.

TABLE I.

Secondary Emission of Oxide-Coated Cathodes Measured by Other Investigators.

T° K.	Maximum Yield	Reference
300	6	Bruining and DeBoer [4]
300	3	Morgulis and Nagorsky [5]
850	14	Morgulis and Nagorsky [5]

2. *Yield vs. Temperature*

It has been previously stated that the yield increases with temperature in an exponential manner. This effect was first verified in this laboratory by means of the beam tube described in Section III, A, 1.

Measurements were performed upon a Baker's Chemical R-500, a standard barium-strontium double carbonate mixture, applied to the nickel target.

In order to retain sufficient galvanometer sensitivity for measuring the secondary electron current while the target was maintained at elevated temperatures, it was necessary to balance out the current due

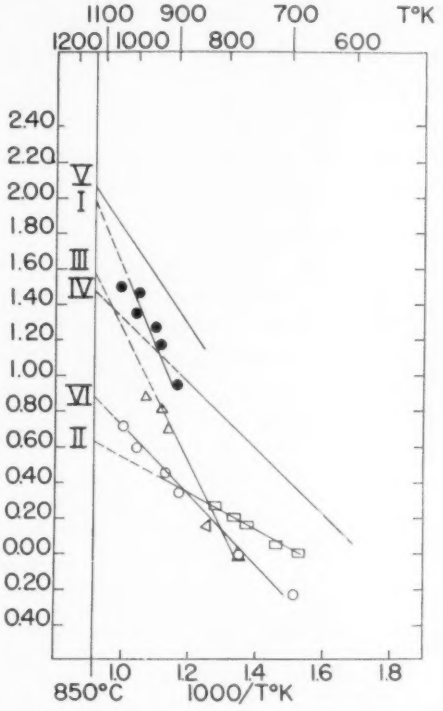

FIG. 9. Typical curves of log $\Delta\delta$ vs. $1000/T°$ K. (see Eq. 16). I. ● S.E. 13: $Q_1 = 1.4$. II. □ S.E. 3 (Badly poisoned screen cathode): $Q_1 = 0.36$. III. △ Beam tube: $Q_1 = 1.4$. IV. Morgulis and Nagorsky:[6] $Q_1 = 0.73$. V. W. E. Danforth,[15] electrical conductivity of oxide-cathode coating: $Q_1 = 1.1$. VI. ○ Spec. S.E. 2: $Q_1 = 0.75$.

to thermionic electrons emitted by the oxide-coating. This was accomplished by means of an arrangement which caused a current equal to the thermionic current to flow in the reverse direction through the galvanometer. The circuit was balanced under the condition of no primary electron bombardment ($V_p = 0$, Fig. 2) and, when the primary beam was turned on, the galvanometer deflection was due solely to secondary electrons from the target. It is to be noted that these considerations detract from the accuracy of the measurements when the bucked-out current greatly exceeds the true secondary electron current.

The value of δ for an oxide coating was determined at various temperatures up to 930° K. Technical difficulties associated with the high

thermionic emission and space-charge effects prevented the attainment of reliable results at higher temperatures with this apparatus. Morgulis and Nagorsky were unable to extend their measurements beyond 850° K.

In Section II, B, 3, it was stated that because of the exponential dependence of yield upon temperature (Eq. 1) it is of interest to plot the logarithm of $\Delta\delta$ (i.e. $\delta_{K.^\circ} - \delta_{300^\circ K.}$) vs. $1/T$.

Figure 9 shows the data plotted in this manner. The extrapolated value of the yield at 850° C. is 44. It was observed that the value of δ depends upon the degree of activation of the coating, as evidenced by the thermionic emission.

TABLE II.

Typical Secondary Emission Yield Data for Oxide-Coated Cathodes.

Tube No.	Type of Coating	Max. Yield $\delta_{max.}$ at Room Temperature	Max. Extrapolated Yield, $\delta_{max.}$ at 850°	Pulsed Thermionic Emission Characteristics of Cathode: Pulse Width = 1 μs. Rec. Freq. = 60 pps.
1	C–51–2 Sprayed on Grade A Ni	6.7	115	18 amps./cm.², emission-limited
5	C–51–2 Sprayed on Grade A Ni	6.8	110	20 amps./cm.², space-charge limited to sparking
9	C–51–2 Sprayed on Grade A Ni	4.7	Not obs.	27 amps./cm.², s.c.l. to sparking
12	C–51–2 Sprayed on Grade A Ni	3.9	124	20 amps./cm.², s.c.l. to sparking
13	Bowie No. 1 Sprayed on Wise No. 1 Ni	5.7	136	20 amps./cm.², s.c.l.
14	50% MgO, 50% C–51–2 Sprayed on Grade A Ni	5.8	106	20 amps./cm.², s.c.l.
6	C–51–2 Painted on 60×60 Ni Screen	3.2	54	13 amps./cm.², emission limited
3	C–51–2 Painted on 60×60 Ni Screen	2.7	7	1.7 amps./cm.² Badly poisoned by diffusion pump oil due to power failure during bakeout

C–51–2 is here used to designate a certain commercial Ba-Sr-carbonate coating with an organic binder. Coating densities were generally approximately 10–12 mg./cm.²

Typical data obtained with an S.E. tube have also been plotted in Fig. 9. Table II is a recapitulation of the data obtained with a typical group of S.E. tubes during the most extensive phase in the life history of a cathode. The essential features revealed by Fig. 9 and Table II may be summarized as follows:

1. The yield from a well activated oxide-coated cathode increases with temperature in an exponential manner, and may substantially exceed 100 at 850° C.

2. In general, the slopes of the curves are of the same magnitude, having Q values of approximately 0.9–1.5 eV.

3. *Yield vs. Degree of Activation*

The intimate dependence of the secondary emission upon the degree of activation of an oxide-coated cathode has been manifest throughout these investigations. In general, when the degree of activation is improved, both thermionic and secondary emission are enhanced. It is difficult to study the exact quantitative relationship between pulsed thermionic emission and δ, but the data which have been obtained indicate the nature of the effect at least qualitatively. This is evident in Fig. 9. A severely-poisoned cathode (II) exhibits a smaller yield than that characteristic of a well-activated cathode (*I*) (see Table II).

TABLE III.

Experiment on the Effect of High-Temperature Flashing upon Secondary Emission and Pulsed Thermionic Emission from an Oxide-Coated Cathode.

Run No.	Pulsed Thermionic Emission Characteristic of Cathode: Pulse Width = 1 μs. Recurrence Freq. = 60 pps.	Secondary Emission Characteristics	
		δ	Temp. C.°
1	15 amps./cm.², space-charge limited		
2		4.8	Room temp.
	Flash cathode >900° C. 30 secs. at 1025° C. max.		
3	Flat at 9 amps./cm.²	2.1	Room temp.
4			
5		5.0	Room temp.
	Flash cathode, 1075° C., 1 minute		
6	Flat at 5–7 amps./cm.²	2.1	Room temp.
		2.7	390
		4.9	470
7			
8		4.0	Room temp.
		6.5	370
	Flash cathode, 1075° C., 3 minutes		
9	Flat at 2.5 amps./cm.²	1.2	Room temp.
		5.2	850
10			
11		3.5	Room temp.
		13.5	850
	Flash cathode, 1110° C., 5 minutes		
12	Flat at 3.7 amps./cm.²	1.4	Room temp.
		11.4	850
13			
14		1.9	Room temp.
		16.9	850

Runs with SE No. 10 are numbered in chronological order.

This effect is further illustrated by the data presented in the next subsection 4 describing the variation of δ during the cathode lifetime.

Several pertinent factors were revealed by an experiment in which the cathode was flashed at temperatures sufficiently high to promote excessive evaporation of metallic barium, thereby disturbing the impurity-level concentration (c.f. Section V, C). The essential data are summarized chronologically in Table III and Fig. 10. The high tem-

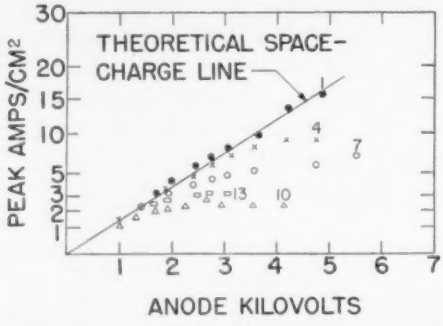

FIG. 10. Current vs. anode voltage measurements obtained in the experiment, summarized in Table III, on the effects of high temperature flashing upon primary and secondary emission from a magnetron cathode. The theoretical line represents the space-charge limited emission characteristic of the particular diode geometry. The numbers on the various curves, run after successive flashings, are those listed in Table III under column heading "Run No." ● Run 1. Initial data. × Run 4. After 30 secs. 1025° C. flashing. ○ Run 7. After 1 min. additional, 1075° C. flashing. △ Run 10. After 3 min. additional, 1075° C. flashing. □ Run 13. After 5 min. additional, 1110° C. flashing.

perature flashing is very deleterious, as is evidenced by secondary emission measurements made immediately after each such treatment. However, marked reactivation occurs even during the course of the comparatively brief pulsed thermionic emission V vs. I run (with the cathode temperature at 850° C.) as is manifested by the subsequently increased secondary emission values.

4. *Yield vs. Cathode Age*

It had been recognized previously that the characteristics of an oxide-coated cathode vary considerably during its lifetime of operation. The Cathode Research Group, Radiation Laboratory, M.I.T., has vividly demonstrated the necessity of studying cathode parameters as a function of life, particularly under the prevailing conditions, heretofore unencountered, associated with the drawing of very high pulsed emissions. It was considered essential, therefore, to subscribe to this precept in the program of secondary emission studies. The measurements listed in Table II are representative of the more stable period during the life of an oxide-coated cathode operating under pulsed conditions.

The life history of a magnetron cathode in an S.E. tube is presented in Table IV to indicate the nature of the trend generally followed. In this case, the coating was quite thin. It was observed that substantial secondary emission (δ equal 50) may still be retained by a cathode whose coating has become barely visible, and of which only slight specks

TABLE IV.

Life History of an Oxide-Coated Cathode.

Run No.	Pulsed Thermionic Emission Characteristic of Cathode: Pulse Width = 1 μs. Recur. Freq. = 60 pps.	Secondary Emission		Ageing Run
		δ	Temp. C.°	
1	Flat at 2 amps./cm.²			
2		5.3	Room temp.	
		55	850° C.	
3				17 hrs. = 13.5 amps./cm.² peaks at end of run: Pulse width = 0.9 μs. Rec. freq. = 400 pps.
4	14 amps./cm.²			
5		6.4	Room temp.	
6				55 hrs. additional, total = 72 hours
7	20 amps./cm.² s.c.l.			
8		5.8	Room temp.	
		106	850°	
9				49 hrs. additional, total = 121 hours
10	20 amps./cm.² s.c.l.			
11		5.8	Room temp.	
		86	850°	
12				67 hrs. additional, total = 188 hours
13	14 amps./cm.² emission limited			
14		4.2	Room temp.	Lead burned out
		54	850°	

Runs with SE No. 14 are numbered in chronological order.

remain after a long life run. Such a cathode can also furnish appreciable pulsed thermionic emission (10 amps./cm.² with 1 microsecond pulse width, 60 pps. recurrence frequency) despite the paucity of coating.

5. *Energy Distribution of Secondaries*

The S.E. tubes were not particularly well adapted to measurements of the energy distribution of the secondary electrons. Because of the theoretical importance of obtaining information in this regard, this phenomenon was studied in detail with another type of experimental tube to be described subsequently. Discussion of this data is deferred until a later section.

(*To be continued.*)

Better Cottons, Better Fabrics.—"You can't tell a book by its cover!" Nor, says the U. S. Department of Agriculture, can you tell the quality and usefulness of cotton by looking at cotton bolls and feeling them—or simply by taking samples from a bale and observing them. Facts on cotton usefulness and quality are determined by the Department through exhaustive scientific tests of commerical varieties each year.

Cottons from the 1944 crop—achieving high marks in spinning and other tests—will benefit the average consumer from one to three years later by furnishing better and stronger cotton fabrics, easier to manufacture and, consequently, cheaper. Cottons which go through these tests really have to "take it." Flaws in performance show up under cold scientific analysis. Good points, also, stand out as a result of exhaustive testing. Tests include thickness of fiber, length, maturity, tensile strength, napiness (tiny knots), strength of corded yarn, appearance, spinning performance and many other factors that determine the bed rock worth of cotton on a factual basis instead of on a guess basis.

From the 1944 crop, some of the major upland varieties which graduated from the hard boiled testing procedures with honors include the following, listed not in order of performance, and all medium staple length.

1. Acala 15–17, grown largely in irrigated areas of the Southwest.
2. Delta and Pineland 14, grown largely across the whole "southern cotton belt."
3. Stoneville 2B, grown largely across the whole "southern cotton belt."
4. Coker 100, grown largely in Georgia and the Carolinas.

Mrs. Housewife will benefit from each of these strains to some extent this year—and more during the next two years. But the research continues yearly for more nearly perfect cotton, and it will continue with the aid of all help science can bring to bear.

R. H. O.

OLIVER HEAVISIDE—HUMORIST.

BY

C. M. HEBBERT, Ph.D.

Bell Telephone Laboratories, New York, N. Y.

Heaviside Layer, *Heaviside's Expansion Theorem* and *Heaviside's Operational Calculus* are commonly heard phrases which do not sound like the writings of their author would constitute source-books of humor. He would not indeed have been featured in a Sunday evening radio comedian's hour, but scattered here and there through his papers filled with long equations and weighty discussions of basic electrical questions are sentences or paragraphs or whole sections revealing a vast knowledge of the lighter modes of expression and a large appreciation of the homely phrase and its power to carry home a point. He even proposed semi-seriously that the name "Heavy" should be used for loading, saying[1] "The *side* should be omitted. I never suffered much from it; they said it was swelled head. *Heavify* and *Heavification* seem to me the best."

Coining names apparently gave him especial pleasure but he was careful to explain why he liked his choice. In the first of a series of Notes on Nomenclature[2] published in *The Electrician* in 1885 and 1886, with the title "Ideas, Words and Symbols," he discussed the pros and cons of names like resistivity, conductivity, permeability, capacity, etc. This note ends by saying "All these things will get right in time perhaps. Ideas are of primary importance, scientifically. Next, suitable language. As for the notation, it is an important enough matter, but still only takes the third place." Then, Note 2, "On the Rise and Progress of Nomenclature," starts off: "In the beginning was the word. The importance of nomenclature was recognized in the earliest times. One of the first duties that devolved upon Adam on his installation as gardener and keeper of the Zoological Collection was the naming of the beasts. Passing over the patriarchal period, the fall of the Tower of Babel and its important effects on nomenclature . . . , and coming at once to the middle of the 19th Century, we find that Mrs. Gamp[3] was much impressed by the importance of nomenclature. 'Give it a name, I beg. Sairey, give it a name!' cried that esteemed lady. She even

[1] Katherine Maynard, "Oliver Heaviside as Seen in his Books and Letters." *The Technology Review*, March, 1933.

[2] Electrical papers, Vol. II, pp. 23–28.

[3] Mrs. Sairey Gamp, midwife and nurse, was a Character in Dickens' novel "Martin Chuzzlewit."

went so far as to give a name to an entirely fictitious personage—Mrs. Harris, to wit—who has many scientific representatives."

"Having thus fortified ourselves by quoting both ancient and modern instances, let us consider the names of the electrical units. A really practical name should be short. . . . If, in addition it be the name or part of the name of an eminent scientist, so much the better. This is quite a *sentimental* matter; but if it does no harm, it is needless to object to it."

"Ohm and volt are admirable; farad is nearly as good (but surely it was unpractical to make it a million times too big—the present microfarad should be the farad); erg and dyne please me; watt is not quite so good, but is tolerable. But what about those remarkable results of the Paris Congress, the ampere and the coulomb? Speaking entirely for myself they are very impractical. Coulomb may be turned into coul and is then endurable; this unit is, however, little used. But ampere shortened to am or amp is *not nice*. Better make it *pere*. . . . Was not Ampere the *father* of electrodynamics?"

"Mac, Tom, Bob and Dick are all good names for units. Tom and Mac (plural, Max) have sentimental reasons for adoption; Bob and Dick may also at some future time. . . . We have much to be thankful for. Consider what frightful names[4] might have been given to the electrical units by the Germans."

In Note 4 on nomenclature (1887) he speaks of "This eminent *scienticulist*[5] who "once declared that $E = RC$, to express Ohm's law, was nonsense; it must be $C = E/R$. . . . It is for the practicians to find practical ways of getting a round peg to fit a square hole."

He must have had a fine time writing the opening paragraph of a paper[6] on "The Earth as a Return Conductor," which follows:

"The daily newspapers, as is well known, usually contain in the autumn time paragraphs and leaders upon marvelous subjects which at other times make way for more pressing matter. The sea-serpent is one of these subjects. This year, however, that interesting animal has not been so observable, which is, perhaps, the reason why an equally wonderful and not less time-honored phenomenon has come to the fore again. There appeared lately an account of the performance of 'an innocent boy' with a stick of wood, which, being held in the hands of the operator as he walked about in a field, twisted and turned itself so as

[4] *The Scientific American*, Vol. 36 (Feb. 2, 1878), p. 68, "one inventor collecting all his energies for one grand effort, triumphantly produced 'doppelstahlblechzungensprecher.' The jaw can be replaced by pressing on the lower molars with the fingers, and guiding the muscles with the thumbs." But, a few pages earlier in the same volume a Philadelphian proposed the name "belophone."

[5] The word "scienticulist" appears again on p. IV of the preface to Vol. II, of "Electromagnetic Theory."

[6] Elect. Papers, Vol. I, p. 190.

to prove the existence and point out the situation of water beneath the surface. This may or may not be. Never having studied the action of divining rods makes me an incompetent judge; but on further reading the explanation of a philosopher[7] of the cause of the phenomenon, viz., that the water was a conductor of electricity, and therefore, the electric currents deflected the wand, I was at once reminded (perhaps strangely, for there is hardly any connection between the theories) of a theory of the action of the earth as a return conductor that I first read some fifteen years ago in a Handbook which has since passed through many editions."

Sometimes his humor carries a barb as in Electrical Paper No. XXIII (Vol. II, p. 28), where he carries on a feud with Prof. Hughes beginning with "We read in the pages of history of a monarch who was '*supra grammaticum*.' All great men are like that monarch. They have their own grammars, syntaxes and dictionaries. No man has a more peculiar grammar than Prof. Hughes. . . . I took great pains in translating Prof. Hughes' language into my own."

About grammar in general he had ideas of his own, expressed as follows:[8] ". . . some critic has made etymological objections. But what has etymology got to do with it? The proper place for etymology is the grammar book. I always hated grammar. The teaching of grammar to children is a barbarous practice, and should be abolished. They should be taught to speak correctly by example, not by unutterably dull and stupid and inefficient rules. The science of grammar should come last, as a study for learned men who are inclined to verbal finnicking. Our savage forefathers knew no grammar. But they made far better words than the learned grammarians. Nothing is more admirable than the simplicity of the old style of short words, as in A sad lad, A bad dog, of the spelling book. If you transform these to A lugubrious juvenile, A vicious canine, where is the improvement?"

One article of a long series (XXXV in Elect. Papers) has the title "The Transfer of Energy and its Application to Wires." But he starts out with a gentle ribbing of a learned contemporary:

"When a sage sits down to write an elementary work he naturally devotes Chapter I to his views concerning the very foundation of things, as they present themselves to his matured intellect. If may be ques-

[7] Regarding the term philosopher see the introduction to "Electromagnetic Theory," Vol. I, p. 5: "For my part I always admired the old-fashioned term 'natural philosopher.' It was so dignified and raised up visions of the portraits of Count Rumford, Young, Davy, etc., usually highly respectable looking elderly gentlemen, with very large bald heads and much wrapped up about the throats, sitting in their studies pondering calmly over the secrets of nature revealed to them by their experiments. There are no natural philosophers now-a-days. How is it possible to be a natural philosopher when a Salvation Army band is performing outside; joyously, it may be, but not most melodiously? But I would not disparage their work; it may be far more important than his."

[8] "El. Th.," Vol. I, p. 404.

tioned whether this is to the advantage of the learner, who may be well advised to 'skip the Latin,' as the old dame used to say to her pupils when they came to a polysyllable, and begin at Chapter II. If this be done, Prof. Tait's 'Properties of Matter' is such an excellent scientific work as might be expected from its author. But Chapter I is metaphysics. There are only two Things going, Matter and Energy. Nothing else is a thing at all; all the rest are Moonshine, considered as Things."

Further on—"it is like this. If a person is in a room at one moment, and the door is open, and we find that he is gone the next moment, the irresistible conclusion is that he has left the room by the door. But he might have gone under the table. If you look there you can make sure. But if you are prevented from looking there, then there is clearly a doubt whether the person left the room by the door or got under the table hurriedly. There is a similar doubt in the electromagnetic case in question, and in other cases."

After deriving some formulas for "self-induction" of a wire of rectangular cross-section he points out some errors in an equation given by Thomson and Tait and remarks "Such little errors will find their way into mathematical treatises; there is nothing astonishing in that; but a certain collateral circumstance renders the errors in their equation worthy of being long remembered. For the distinguished Authors pointedly call attention to the astonishing theorems *in pure mathematics* to be got by the exchange of a and b, such as rarely fall to the lot of pure mathematicians. They were miraculous!"

Tilting with the mathematicians occupied a great deal of space in his articles because his unorthodox methods were frequently so sketchily explained as to shock the conservative rigorists of that time. But he says[9] "Even Cambridge Mathematicians deserve justice. . . . We must take the good with the bad, in this as in other matters; and though legitimate and serious objection may be raised to the distressing and soul-destroying style in which some Cambridge mathematicians do their work, and to the unpractical conservative tendency that exists . . . , we should also bear in mind the great volume and value of the work done, and not unduly depreciate or make invidious comparisons.—Now, it has come to my knowledge that a man who is not a Cambridge Mathematician and who does not pretend to be much of any sort of mathematician, but who is a practical physicist—recently made the discovery that a certain unconventional mode of treating the mathematics of the question (explained to him by myself) conducted him immediately to the exact solution of the problem he had in hand (on

[9] "Mathematics—and Mathematics." Remarkable phenomenon—"Electromagnetic Theory," Vol. II, pp. 10–12.

the age of the earth). Of course, he has no prejudices[10] of the rigorous kind; but makes use of what he finds useful, as soon as he has gotten to know how to go to work.—For this reason, I shall have no further hesitation in making use of the method—in the course of this work, at least in such simple cases as the above experience shows are fairly and without much trouble within the reach of practical physicists and electricians; not mathematicians of the Cambridge or Conservatory kind, who look the gift-horse in the mouth and shake their heads with solemn smile, or go from Dan to Beersheba and say that all is barren; but of the common field variety, who take the seasons as they come and go, with grateful appreciation." In a later paper[11] he remarked concerning the use of operators in the solution of differental equations, "The matter has a great future—as academical mathematicians will find out in time, if they live long enough."

Some lines[12] regarding certain surprising results sound like copy for present-day propagandists. "The human mind is so made as to be capable of believing anything, no matter how silly, provided it is imprinted heavily enough. This is well known to all astute people—to those priests in particular who convert men and women into sheep by saying the same thing over and over again.—The incredibility of results is no evidence by itself of necessary error. The reasoning man may not believe till he sees it; that does not imply disbelief, but a reserved attitude waiting for more light."

Sometimes it took quite a while to get his sense of humor working when the shoe was on the other foot, as he admits in a parenthetical paragraph[13] as follows: "(—For the benefit of the unitiated, I should explain that *El. Pa.* means my 'Electric Papers.' They can be picked up cheap, because the remainder was sold off in quires for a few pence per volume, on account of the deficiency in storage room. So look in the four-penny boxes. Though somewhat vexed at first by this disposal of my laboured lucubrations, it has, later, given me and others occasion for much laughter)."

Sir Oliver Lodge was among the earliest to appreciate Heaviside's work. In a footnote to a lecture[14] given at the Royal Institution on the evening of March 8, 1889, he says "And of one whose name is not yet on everybody's lips, but whose profound researches into electro-magnetic waves have penetrated further than anybody yet understands into the

[10] This idea appears again in a paper "On Operational Methods in Physical Mathematics" (*Roy. Soc.*, Feb. 1893), "and, as regards the following brief sketch, however imperfect it may be, it has at least the recommendation of having been worked out in a mind uncontaminated by the prejudice engendered by prior knowledge acquired at second hand: I do not say it is the better for that, however."

[11] "Electromagnetic Theory," Vol. III, p. 207.

[12] *Electrician*, Vol. 45 (1900), p. 445.

[13] *Electrician*, Vol. 46 (1901), p. 866.

[14] "Modern Views of Electricity" (1889), p. 372.

depths of the subject, and whose papers have very likely contributed partly to the theoretical inspiration of Hertz—I mean that powerful mathematical physicist, Mr. Oliver Heaviside." Lodge carried this admiration to the end and was invited by the editor of the *Electrician* (in which so much of Heaviside's work had been published) to write an account[15] of his life and work just after Heaviside's death in 1925. After giving a resumé of important contributions Lodge wrote:

"Heaviside had, however, a peculiar vein of humour, and sometimes his writings amused, even though they did not edify. . . . The peculiarity of his modes of expression rather alienated, for a time, and perhaps even to this day, the majority of Cambridge mathematicians; for, though there is much originality, there is little orthodoxy in his manner of presentation."

In spite of this "little orthodoxy," it now appears that the Editor of the *Electrician*[16] spoke truly when he said:

"A chapter is closed; but a new chapter is opened. Among much uncertainty nothing is surer than that Heaviside's name will live for evermore in the gallery of scientific heroes."

[15] Lodge, "Oliver Heaviside. An Appreciation: The Personal Equation: The Work of a Genius Elucidated." *Electrician*, Vol. 94 (Feb. 13, 1925), pp. 174–5.

[16] Ibid., p. 172.

NOTES FROM THE NATIONAL BUREAU OF STANDARDS.*

NICKEL PLATING ON STEEL BY CHEMICAL REDUCTION.

A process has been developed by Abner Brenner and Grace E. Riddell of the Bureau's Electrochemistry Section for nickel-plating steel without the use of an electric current. The deposition is brought about by the chemical reduction of a solution of a nickel salt with hypophosphites. The reaction is catalyzed by steel and nickel, and deposition of nickel occurs only on the surfaces of these metals. Because of its cost this process will not displace electro-deposition, but it should have certain special applications, such as the plating of articles that cannot be electroplated satisfactorily.

NEW CIRCULAR ON UNDERGROUND CORROSION.

Circular C450 by Kirk H. Logan, released last month, is an assembly of results of the Bureau's investigations of underground corrosion that began in 1922. The fundamental causes and processes of underground corrosion are the same as those associated with air and water, but their relative values are different. Corrosion in soils is, necessarily, the result of soil characteristics and conditions, but these are so numerous and complex that it is impossible to correlate corrosion with any single soil property.

The results of tests given in this Circular indicate that ferrous materials in common use do not differ greatly in their resistance to soils and that apparent relative merits are either accidental or dependent on local conditions. Low-alloy ferrous materials lose weight more slowly than those that are unalloyed, but they are penetrated just as rapidly. Alloys high in nickel and chromium are very resistant to corrosion.

In most of the soils included in these investigations, the rate of corrosion decreased as the exposure was prolonged. Any corrosion rate is applicable only to the area of metal tested and to the actual period during which it was exposed. The life of a pipe cannot, therefore, be predicted solely from the loss in weight or the depth of a pit as determined over a single period. The corrosiveness of a soil can be indicated only by a formula that takes account of the characteristics of the soil, the change in rate of corrosion with time, and the area of the exposed metal.

The data in the Circular show that copper, and alloys high in copper,

* Communicated by the Director.

corrode much less and more uniformly than ferrous materials. Lead, although resistant to many soils, pits deeply in some of them.

The effectiveness of metallic coatings depends on the soils to which they are exposed; no one of them is suitable for all soils. Bituminous coatings greatly retard loss of metal, their effectiveness being roughly proportional to their thickness. Unfortunately, very few of these coatings are entirely free from pin holes and other imperfections. In this connection, important causes of failure are improper application and injuries received while laying the pipe. Better tools and methods have reduced the failures from these causes, but it is still difficult to secure a completely protected pipe, and even after the pipe is in place, the coating may be injured by soil stress and the roots of trees, shrubs, and grass. The results of tests on a number of promising coatings, developed in the laboratory, are presented.

Several procedures for testing soils and coatings are described, and corrosion prevention methods are compared. Cathodic protection is shown to retard or prevent corrosion under most soil conditions (*Technical News Bulletin No. 313* (May 1943)). Methods of applying cathodic protection are briefly described.

Six appendices give details of test methods and apparatus that are referred to in the body of the text.

Copies of C450, bound in blue buckram, are obtainable from the Superintendent of Documents, Government Printing Office, Washington 25, D. C., at $1.25 each.

FIRE RESISTANCE OF HEAVY TIMBER CONSTRUCTION.

Although heavy timber or "mill" construction floors have withstood fires better than lighter unprotected wood construction, no information has been available on how long they withstand fires of the severity used in the standard furnace test. Experiments recently concluded at the Bureau under the direction of S. H. Ingberg, show that the limit of resistance of such floors, with the lower face exposed to fire, is determined either by failure under representative working loads or by occurrence of flame or ignition of combustible material on the upper side.

With a 1-inch finish floor on top, the fire resistance of laminated floors of 4-inch planks on edge averaged 45 minutes; with 6-inch planks, a little over 1 hour; and with 8-inch planks, about 1½ hours. With the structural portion of the floor of tongued and grooved plank of 3-inch nominal thickness laid flatwise, the fire resistance was approximately 45 minutes. Impregnation of the wood with fire retarding chemicals increased the fire resistance of 4-inch floors by about 15 minutes. A comparable increase was obtained with a heavy coating of a fire-retarding compound on the lower surface.

ENERGY CONTENT AND MOLECULAR STRUCTURE OF HYDROCARBONS.

At the April meeting of the American Chemical Society, Frederick D. Rossini summarized the results of 15 years work at the Bureau on the thermochemistry of the simpler hydrocarbons. His report described the relations existing between energy content and structure for hydrocarbons of the following classes: Paraffins, olefins, acetylenes, aromatics, cyclopentanes, and cyclohexanes. Energy is one of the most important properties of matter, and its efficient utilization in manufacturing and refining requires adequate knowledge of the fundamental values of the compounds involved in the given processes.

PRECISION OF TELESCOPE POINTING FOR OUTDOOR TARGETS.

When a telescope is pointed at a target, and the intersection point of the cross-hairs is set on the image formed by the objective and seen through the ocular, accidental (non-systematic) errors are present that prevent the observer from reproducing exactly the same pointing in successive settings. These errors may be attributed in part to the mechanism employed in pointing the telescope, and in part to errors dependent upon the combination of target nature, optical path, optical characteristics of the telescope, and personal errors. A recent study by Francis E. Washer and Helen B. Williams has been concerned with determining the probable error of a single pointing under average outdoor conditions when the errors arising from the mechanism are eliminated. To accomplish this the telescope was mounted rigidly and left undisturbed during the course of a series of observations. The image of the target was moved with respect to the cross-hairs by means of a weak prism, placed in front of the objective, which was capable of rotation about its vertical axis. With this apparatus, the probable error of a single pointing was measured for a group of outdoor targets placed at distances ranging from 100 to 13,600 meters from the observer. Observer differences for both outdoor and indoor targets were studied.

In the course of the investigation, it was found that, when distance is neglected, the probable error of a single pointing is $\pm$ 0.62 $\pm$ 0.01 second. While, for practical purposes, distance can be neglected, when it is over 100 meters, it is interesting to note that the formula,

$$PE_s = \pm (0.064\, d^{1/4} + 0.19) \text{ second},$$

where d is the range in meters and PE_s is the probable error of a single pointing, gives fair agreement with the measured values of PE_s. Differences were found for right and left-eye pointing for six observers. In addition, the precision of outdoor pointing was affected by long period errors that cause the mean value to shift during the course of an extended series of observations. The complete report on this study will be published as RP1717 in the May number of the *Journal of Research*.

Virus Disease Challanges Research.—A virus disease that may attack man, although it is mainly important in horses and mules, is now one of the more important subjects of veterinary research. Equine encephalomyelitis belongs to the same general group of diseases that includes poliomyelitis and St. Louis encephalitis in man, but the horse infection, which has been recognized as a virus disease since 1930, has several features which make it of special interest to research workers.

It is well established now that mosquitoes can transmit the disease to the horse and to other warm blooded animals, including birds. One confusing feature is that there are two distinct strains, known as "western" and "eastern." The disease has been reported from all but three of the States—Pennsylvania, Tennessee and West Virginia—according to a recent review of the situation by M. S. Shahan and L. T. Giltner, U. S. Department of Agriculture veterinary research workers. In three States—Alabama, Texas and Michigan—both strains have been identified. A third strain, very similar, has been found in Venezuela and in some other Latin America areas. Cuba and Mexico have the "eastern" strain and Argentina has the "western" type.

The Bureau of Animal Industry has had reports of more than 500,000 cases since 1935, and estimates that there have been at least 1,000,000 cases in the United States since 1930. Discouragement over loss of work animals, says the report, has been a factor in causing substitution of tractor power on some farms.

Since 1938, when an effective vaccine was developed from virus cultured on chick embryo, it is estimated that more than 7 million 2-dose vaccinations of animals have been made. This gives satisfactory protection, but must be repeated each year, and in the three areas where both strains exist double vaccination is required since the vaccine from one strain does not protect against the other.

Veterinary scientists have not been able to find the source or "reservoir" in which the infection lives over from year to year. Apparently horses do not harbor the disease over winter. It may live over in birds or some animal or possibly in some such carrier as a tick.

If mosquito control becomes practical—as seems possible with widespread use of DDT—the veterenarians think this may help reduce losses from equine encephalomyelitis.

R. H. O.

THE FRANKLIN INSTITUTE.

STATED MONTHLY MEETING, WEDNESDAY, MAY 15, 1946.

After the playing of the National Anthem, Mr. Charles S. Redding, President, The Franklin Institute, called the meeting to order and announced that this was a regular monthly meeting of the Institute.

He announced that a program of Medal Day events, which constituted the stated monthly meeting for April, would appear in the May issue of the JOURNAL, and that at this meeting members were asked to approve the minutes of the March meeting as printed in the April JOURNAL.

No protest was entered and the minutes were declared approved as printed.

The Secretary, Dr. Henry Butler Allen, made the following report from the Membership Department. The elections for April were omitted from last month because of the award of medals. They are given herewith:

New Members	*April*	*May*
Active	57	55
Associate	29	28
Student	23	28
	109	111

Total membership as of April 30, 1946 5,516

Mr. Redding called attention to the fact that this is the third lecture on the Charles Day Lecture Foundation, established as a memorial to Mr. Charles Day, former officer and member of the Board of Managers of The Franklin Institute.

As there was no further business, he then introduced the speaker of the evening, Dr. James Creese, President, Drexel Institute of Technology, who spoke on "A Layman's View of Law and Labor."

The meeting adjourned at 9:30 P.M., with a vote of thanks from an interested and enthusiastic audience.

HENRY BUTLER ALLEN,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of Stated Meeting held Wednesday, May 8, 1946.)

HALL OF THE COMMITTEE,
PHILADELPHIA, May 8, 1946.

DR. HIRAM S. LUKENS, *in the Chair.*

The following report was presented for final action:

No. 3151: Work of Vladimir Kosma Zworykin.

This report recommended the award of a Howard N. Potts Medal to Vladimir Kosma Zworykin, of Taunton Lakes, New Jersey, "In recognition of his outstanding contributions to the science and art of television which he has advanced not only through the invention of the Iconoscope in which the principle of storage and integration of image light was first employed, but also through the development of the accessory equipment, including the Kinescope, needed in complete commercial television."

JOHN FRAZER,
Secretary to Committee.

LIBRARY NOTES.

The Committee on Library desires to add to the collections any technical works that members would wish to contribute. Contributions will be gratefully acknowledged and placed in the library. Duplicates received will be transferred to other libraries as gifts of the donor.

Photostat Service. Photostat prints of any material in the collections can be supplied on request. Orders received in the morning are filled the same day. The average cost for a print 9 × 14 inches is thirty-five cents.

The library and reading room are open on Mondays, Tuesdays, Wednesdays and Fridays from nine o'clock A.M. until five o'clock P.M., Thursdays from two until ten o'clock P.M., Saturdays from nine o'clock A.M. until twelve noon.

RECENT ADDITIONS.

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BUCHANEN, ROBERDEAU. The Mathematical Theory of Eclipses. 1904.

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American Radio Relay League. The Radio Amateur's Handbook. Twenty-Third Edition. 1946.

BRAYMER, DANIEL H., AND A. C. ROE. Repair-Shop Diagrams and Connecting Tables for Lap-Wound Induction Motors. Second Edition. 1946.

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PÓLYA, G., AND G. SZEGÖ. Aufgaben und Lehrsätze aus der Analysis. Bd. 1–2. 1945.

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WALKER, JAMES, AND CARL C. TAYLOR. Simplified Punch and Die Making. 1946.

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American Institute of Mining and Metallurgical Engineers. Transactions. Volumes 161 and 162. 1945.

BRIGGS, CHARLES WILLERS. The Metallurgy of Steel Castings. First Edition. 1946.

EASTWOOD, L. W. Gas in Light Alloys. 1946.

HALL, NATHANIEL, AND G. B. HOGABOOM, JR. Dictionary of Metal Finishing Chemicals. 1945.

SHEPPARD, RICHARD. Cast Iron in Building. 1945.

WEIN, SAMUEL. Metallizing Non-Conductors. 1945.

RAILROADS.

MARSHALL, JAMES. Santa Fé. 1945.

Railway Engineering and Maintenance Cyclopedia. Sixth Edition. 1945.

NOTES FROM THE BIOCHEMICAL RESEARCH FOUNDATION.

Abstract of **Ribonucleinase. III. The Behavior of Copper and Calcium in the Purification of Nucleic Acid and the Effect of These and Other Reagents on the Activity of Ribonucleinase.**—CHARLES A. ZITTLE (*Journal of Biological Chemistry*, **163**: 111, 1946). Copper and calcium, both present in commercial nucleic acids, accompanied the insoluble high polymer fraction when a nucleic acid solution was precipitated with acetic acid. Copper inhibited ribonucleinase, and when the amount of copper present in the crude nucleic acid was relatively large it became noticeably inhibitory when the precipitated nucleic acid was used as the substrate for ribonucleinase. The presence of calcium apparently had no effect on ribonucleinase. A substance was present in some lots of nucleic acid which prevented the inhibition of ribonucleinase by copper until a certain concentration of copper was exceeded. Copper and zinc apparently inhibit by the formation of an inactive dissociable complex with the enzyme. Zinc was almost as inhibitory as copper; other metals tested had a negligible effect; phenylmercuric acetate was inhibitory. Iodoacetate and iodoacetamide, -SH reagents, also inhibited ribonucleinase. Contrary to the action of each on other enzymes, iodoacetic acid was more inhibitory than iodoacetamide. Arsenite, selenite, cystine, and maleic acid had no effect on ribonucleinase.

Abstract of **Ribonucleinase. IV. Hydrolysis of Ribonucleic Acid by Ribonucleinase and by Sodium Hydroxide.**—CHARLES A. ZITTLE (*Journal of Biological Chemistry*, **163**: 119, 1946). The course of hydrolysis of ribonucleic acid was measured by precipitation of the unhydrolyzed nucleic acid with uranium chloride in trichloroacetic acid; the optimum pH for the use of this reagent was shown to lie at or below pH 1.00. The incomplete hydrolysis of ribonucleic acid by ribonucleinase was confirmed and hydrolysis was found not to be increased by the removal of the hydrolytic products, the mononucleotides. A streptococcus ribonucleic acid was incompletely hydrolyzed to the same degree as the yeast ribonucleic acid with which these observations were made. Hydrolysis of ribonucleic acid by sodium hydroxide (0.16 N) at 25° was complete in 18 to 22 hours under favorable conditions; some samples of nucleic acid were not hydrolyzed in this time. Ribonucleic acid that had been hydrolyzed with sodium hydroxide to an extent that exceeded the maximum obtained with ribonucleinase was still quite reactive with the enzyme. Ribonucleic acid subjected to maximum hydrolysis with ribonucleinase was more slowly hydrolyzed with sodium hydroxide than the parent nucleic acid.

BOOK REVIEW.

A Guide to the Literature on the History of Engineering Available in the Cooper Union Library. Cooper Union Bulletin. Engineering and science series, Number 28, 46 pages, 18 × 25 cms., paper. New York, The Cooper Union for the Advancement of Science and Art, 1946.

Although this bibliography lists only the resources of one library, it should prove a useful guide to those interested in engineering. There are 629 entries presented in a classified arrangement covering practically all phases of engineering. Important periodical articles have been included in addition to books and pamphlets. Three indexes facilitate the use of the list: an historical classification—a subject rearrangement in chronological form of some of the items; an author index; and a subject index. The list is a good example of the type of bibliographical check-list that a library may compile based on its holdings and issue as an aid to scholarly research.

G. E. Pettengill.

PUBLICATIONS RECEIVED.

The Science and Art of Perfumery, by Edward Sagarin. 268 pages, illustrations, 14 × 20 cms. New York, McGraw-Hill Book Co., Inc., 1945. Price $3.00.

Advancing Fronts in Chemistry, Volume II, Chemotherapy, edited by Wendell H. Powers. 156 pages, illustrations, 16 × 23 cms. New York, Reinhold Publishing Corporation, 1945. Price $3.25.

CURRENT TOPICS.

Some Electronic Applications.—"Few branches of engineering can claim less elapse of time between the engineer's dream and the finished, working article, than electronics," said E. H. Alexander of General Electric recently. One of the most thought-provoking fields for future growth is the use of micro-waves for industrial purposes. The great strides made during the war with micro-waves (radar) for detection, direction, recognition and navigation open a new field. These ultra-high frequency radiations have some promise of supplanting light beams now used with photoelectric relays and their unique transmission possibilities of being "piped" around corners are interesting. Such waves (in the vicinity of 3,000 megacycles) can be polarized, reflected and absorbed, suggesting some of the properties of light. For instance, the transparency of paper, thin wood and coarse wire screens to these waves compared with the opaqueness of wet paper, wet cloth and fine wire screens suggests many uses. Just one is a moisture-content controller for a continuous process industry. A thickness gage is another possibility. Any metal surface reflects the micro-wave beam; it need not be a polished surface. Although the human body absorbs the waves, it will also reflect waves of sufficient intensity.

Already several future industrial applications of this new electronic tool are in developmental stages. The principle of the proximity fuse, for example, developed for explosive shells might find application in railway signalling or train control, who knows.

Stepping down a little in the frequency spectrum, from 3,000 megacycles to the range of 3 to 40 megacycles, we find electronic sources for dielectric heat increasing the productivity of many machines or processes and, indeed, the worker himself. Notably, the use of dielectric heat in the plastics moulding industry has been gratifying. Preheating of "sills" or "preforms" increases the product of the machine; allows the same piece to be moulded on a smaller press; and improves the quality of the finished piece. The drying of synthetic and natural fibers or yarn, while in continuous motion, seems justified because of improved quality and tensile strength. Even food technologists are looking to this source of internal heat for de-hydration and sterilization of food products.

Controlled electronic rectifiers have been used to supply regulated power to direct-current motors for more than 18 years, but only within the past four years has a packaged system for a complete, wide-range, variable speed drive come into its own. During this short period of rapid expansion we have seen a previous limit of 15 h.p. extended to an operating installation of a 40-h.p. drive. Now a 75-h.p. drive is in the building and we already look with eagerness to a prospective 600-h.p. drive. Electronic motor control for ship propulsion and even main-line locomotive drives is in the offing.

The technique of the television camera has been suggested as a means for the inspection of surfaces of materials in motion such as strips of metal, cloth and rubber. There are, of course, many problems to be solved, particularly

what to do with a signal of imperfection. However, no apparently insurmountable object stands in the way of accomplishment. Who knows but what centralized quality control system of the future will have instantaneous and integrated pictures at one central point of the quality of several remote continuous processes. The accomplishment of this feat stands a much better chance than, for instance, the radical improvement of the induction motor or the power transformer.

R. H. O.

Gold in Georgia.—The most complete report to date on gold deposits in Georgia has been placed on open file by the Geological Survey and may be inspected by interested persons, W. E. Wrather, director of the Survey, has reported to Secretary of the Interior Harold L. Ickes.

Georgia now produces only a very small amount of gold but in the past there has been active prospecting in the State at various times.

In 1934 and 1935, with an allotment of PWA funds, the Geological Survey investigated some 500 properties in North Georgia which were reported to contain gold in placers, lodes, or both. These deposits are all described in detail in the report now made available.

The report also summarizes the available information culled from former reports, published and unpublished, concerning many deposits which are not accessible to the United States geologists at the time the investigation was made.

Geologic and topographic maps, cross sections, and mine maps accompany the report.

Persons directly interested in the development of these deposits may inspect copies of the report at the office of the State Geologist, State Division of Conservation, Atlanta, Ga., or at the offices of the Geological Survey in Washington.

R. H. O.

New Food Packages Coming.—Housewives are going to meet many old friends in new dresses on the shelves and counters of food markets in the next few years; and there will be nifty post war models for many foods that have never worn anything more stylish than a wrapper.

Changes were coming fast in the years before the war, says a recent survey report by the U. S. Department of Agriculture. The war, which interrupted so much progress, did not check advances in this field. Instead, it caused a speeding up of innovations in packaging. "Preparation of foods for military and lend-lease shipment promoted experiments to meet extremes of war conditions," the Bureau of Agricultural Economics comments. At home, conditions forced "wide changes in civilian packaging." With labor scarce, food dealers went ahead with the use of semi-automatic machines for packing foodstuffs.

In the next few years the markets are going to put on display the results of all this forced-draft experimenting, adopting the best of the experience and dropping out the less-useful and too-expensive devices. There are new and stronger cardboards and fiber-boards for the larger packages, broad gains in the variety and utility of plastics—particularly for checking evaporation or absorption of moisture by the packaged foods.

Some of the changes sure to come, says the Bureau, are: (1) more pre-packaging of fresh fruits and vegetables; (2) more pre-packaging of fresh meats; and (3) better and more effective packages for many foods that housewives have known well in packages that afford poorer protection.

One factor working in these directions is "the interest of self-service operators in eliminating completely the sale of bulk foods from their stores." Also, "protection against loss of weight and against bruising and spoilage is promised by pre-packaging."

The Bureau points out that there will be savings in transportation costs when products are trimmed for packaging at an early stage in the marketing.

In stores that have been largely on a self-service basis, the tests of pre-packaging of fresh meats have been highly satisfactory. "Large self-service stores," the Bureau reports, "have achieved greatly increased volume and substantial reduction in the ratio of pay roll to sales, compared with other stores in which the meat department is on a service basis." Relaxation of rationing, and eventually of price controls is expected to give a big boost to pre-packaging of meat.

R. H. O.

DDT Aids Protective Strategy.—DDT, the new insecticide, makes more important than ever one field of strategy in man's war against insect pests. This, in turn, calls for new research to develop this strategy that has shot into new importance, say U. S. Department of Agriculture scientists.

The "protective zone" is not new in fighting insects, but has not been used effectively against many pests. One example has been a creosote barrier line to protect corn by preventing the crawling migration of chinch bugs from grain fields. DDT has improved the possibilities for protective zone strategy by creating a new form of contact poisoning.

An early application was with bedbugs. Here science takes advantage of the simple fact that, to live, this pest must have an occasional blood meal. The entomologists say spraying bed and mattress with a suitable DDT preparation is all that is necessary, although more general treatment of infested rooms will eliminate the bugs sooner. The pests must come to the sleeper to survive and they can not reach him without passing over the treated area. By their nature they are driven to their doom.

Spraying screens with DDT is a variation. Mosquitoes and flies that alight on the treated mesh die. But DDT also protects by killing tiny gnats and midges that otherwise make their way safely through unsprayed screening.

Another important use of this "protective zone" strategy is in grain bins. DDT is fine to mix with seed grain for protection against insect injury, but it is poisonous and must not be mixed with grain that is to be used for food or feed. Before the grain is stored, however, it has proved practical to spray an empty bin leaving a long-lasting deposit of DDT in cracks and on the surface. When weevils and other insects that have been lurking in the bin structure move to the newly stored grain they must pass through this deadly protective zone—and DDT kills most kinds before the insects can injure the grain.

Entomologists point out the need for reviewing available information and for research into the lives and habits of the various stages of insect pests.

When these facts—known as "life history"—are clear, it is often possible to make effective and economical attack on a pest at its most vulnerable stage, taking advantage of some fact in its habits and way of life. This may call for applying DDT at a stage when the insect can not avoid the effect. But it takes time and patient scientific effort to discover such facts. With new facts revealed by such research, DDT may be expected to become increasingly effective in development of protective zone strategy against the many insects to which this new poison is deadly.

R. H. O.

Synthetic Rubber Manufacturing Aided by Former Nazi-used Compound.—Production of a new compound which imparts to synthetic rubber a tackiness which aids its fabrication into finished products has been announced by George W. Burpee, president of the General Aniline and Film Corporation, New York. Known as koresin, this new compound also has possibilities in the manufacture of varnishes and lacquers. He said that present production is on a pilot plant scale, but that plans are being completed now to meet the full commercial demand, pointing out that various manufacturers are now experimenting with this new product, which has indicated uses in many industries which fabricate synthetic rubber, particularly in the making of products which call for the building up of plies of rubber.

Mr. Burpee also disclosed that koresin was first made in this country last spring after our armies had penetrated into Germany and had discovered that the Nazis were using a tackifier which appeared to have far superior qualities in fabricating synthetic rubber. The Rubber Reserve Corporation obtained a brief description of the manufacturing process and of the properties of koresin and on May 1 of this year turned over this information to the central research laboratory of the General Aniline and Film Corporation, which had been engaged in various developments calling for the use of high pressure and high temperature reactions of aceytelene. Using their specialized knowledge of these chemical techniques they produced by May 9 samples of koresin which they forwarded to Rubber Reserve laboratories for evaluation. Four days later they had completed the first pilot plant run on several hundred pounds of the new product. By May 25 Rubber Reserve's laboratories had approved the quality of the product and General Aniline had shipped sizeable quantities of koresin to 27 rubber companies for further evaluation. Since then substantially the entire rubber industry in this country has been supplied with samples of koresin for evaluation and testing.

"Our American-made product appears to be identical with the German koresin and equally effective," Mr. Burpee said. "In view of the recent announcement of the Rubber Manufacturers Association that synthetic rubber has established itself permanently as a basic world raw material and that broader fields for its use and service are in sight, the American development of this special tackifier is of commercial and industrial significance. Chemically, koresin is a synthetic resin, a tertiary butyl phenolacetylene condensation product."

R. H. O.

Probable Use of Atomic Power.—The most probable utilization of nuclear energy, the basis for the atomic bomb, is as a source of heat, according to heads of engineering and research for the General Electric Company, in answer to many questions received from industry and the general public alike, asking about the potentialities of atomic power.

Concerning the possible use of nuclear energy as a source of power to heat and light homes and buildings, operate factories, propel ships, locomotives, airplanes, and automobiles, Harry A. Winne, G-E vice-president in charge of engineering policy, and Dr. C. Guy Suits, vice-president and director of the G-E Research Laboratory, predicted that several prospective uses of nuclear energy will become technically possible, but that it is too early to predict whether such uses will be economically practical.

In stating that the most probable utilization of nuclear energy is as a source of heat, the General Electric officials said that such heat in turn may produce steam or hot gases for use in conventional types of power generating equipment.

"Some people have asked concerning the possibility of direct conversion from nuclear energy to electric power in usable form. This seems to us an extremely remote possibility," said Mr. Winne and Dr. Suits. "There is a long road of development ahead. It is true that the success of the bomb demonstrated that we can release a tremendous amount of nuclear energy in one instantaneous blast, at a controlled time. But to make this form of energy commercially useful, we must learn how to generate it and control it in a way that is adaptable to power production. We have no doubt that we shall learn how to do this, but the learning will take a lot of research, development, and time."

Concerning the dangers to human life which result from the radiation accompanying nuclear energy, they said, "Obviously, if we should have to encase a nuclear power plant in many feet of lead or concrete, it would lose some of its attractiveness. Here also, we believe, we shall find a practical solution to the problem, but, again, this will take time."

Most difficult to answer is the question of the economic practicability of the commercial use of nuclear energy, the G-E officials explained. The $2,000,000,000 cost of the atomic bomb program unquestionably could be reduced greatly if a similar project were to be started today based on the knowledge already gained through this development, but it would still be a tremendously costly undertaking, they said.

To control power stations, railroads, or other businesses in which the generation or use of power is of extreme importance, the G-E engineering and research chiefs gave the following advice: "Were we responsible for conducting the affairs of such organizations, we should go right ahead with our plans for the years to come on the basis of present-day commercially available sources of energy; namely, coal, oil, and water power. Only as research and development proceed shall we learn the limitations and possible practical commercial applications of nuclear power."

Many scientists and engineers were assigned by General Electric to the atomic bomb project. Mr. Winne supervised the development and production of apparatus manufactured in virtually every G-E factory for the Government plants which produced the bomb. Dr. Suits directed G-E research activities on the project. As early as 1940, two members of the Research Laboratory

staff, Dr. K. H. Kingdon and Dr. H. C. Pollock, were among the first to isolate uranium 235, used in nuclear energy research and in the manufacture of the atomic bomb.

R. H. O.

The Rotascope.—General Electric engineers with the aid of a newly-developed instrument—the Rotascope—now are able to make any rotating object appear motionless before their eyes.

The blade of an electric fan, or an airplane propeller, will appear to stand still, even though they're whirling at full speed, when the "optical engineer" is focused upon them.

Developed for the study of airplane propellers under actual operating conditions, the Rotascope is the first instrument of its kind which allows the continuous viewing of a rotating object at any point on the perimeter (or path of travel), according to Norman F. Barnes, engineer in the company's General Engineering and Consulting Laboratory here.

The new device is an answer to the scientific problem for an optical system capable of untwisting the light of rotating equipment before it is recorded by the human eye, he said.

It eliminates the rotary component of motion, but shows any flutter or vibration of the moving part, thereby making it possible for scientists and engineers to make a thorough study of the rotating parts of machinery, Mr. Barnes explained.

Engineers can actually see what happens to any of the rotating objects while under the "strain" of thousands of revolutions per minute.

Lowest speeds as well as speeds up to 2,000 revolutions per minute can be studied with the Rotascope, Mr. Barnes said, explaining that special designs of the instrument can be made for the study of higher speeds.

The "optical engineer" also may be used in industry for the study of angular motions, particularly those of low angular velocities.

R. H. O.

Telephones on Power Lines.—"Now it can be tried," was the V-J Day thought of electrical engineers interested in "carrier" telephones that operate with the aid of electric power lines. Carrier telephone service centers around the idea of making one set of poles and wires do the work of two in bringing both telephone service and light and power to farms in thinly settled parts of the country where line cost is an important part of the expense for either service.

In power line carrier service the power wires carry their normal load of low-frequency high-voltage power, and also a hitch-hiking low voltage current of high frequency (similar to radio) that is the basis of telephone service. Both services are carried over the power lines, but the two currents do not mix or interfere with each other.

Before the war interrupted research and experimentation on the carrier system, engineers of the Rural Electrification Administration and the Bell Telephone Laboratories had made progress toward this goal. V-J Day allowed them to resume work, and this accounts for the opening of practical testing of working equipment for a handful of telephone patrons who are also members of a REA financed cooperative serving the Brookland neighborhood near Jonesboro, Ark.

A regular dial telephone is used but new equipment devised by REA and Bell engineers must be installed to transmit the voice over the power lines. Electronic devices are used at both the switchboard and the subscriber's end of the line. This equipment has come through the experimental stage and is now being tested under practical day-to-day conditions of service. One of the devices, a "coupler" located on the power pole, allows the carrier current to enter or leave the power line, but prevents power current from entering the telephone.

Engineers expect that further modifications and simplifications of carrier equipment may be necessary. They regard carrier telephone prospects as highly promising.

R. H. O.

Silver Half Dollar Made Radioactive With Hundred Million Volt Betatron.—An ordinary silver half dollar can be made to give off rays like those of radium by a few minutes exposure to the intense X-ray stream produced in the new 100,000,000-volt betatron at the General Electric Research Laboratory here. This is truly transmutation of elements, but an expensive and impracticable way of doing it!

A Geiger counter was used to show the effect. The counter detects rays from radium and also those from the cosmic radiation which is continually bombarding the Earth from outer space. About thirty times a minute, normally, there is a click from the instrument as a result of a cosmic ray.

A half dollar, borrowed from one of the visitors, was inserted in the counter, and no effect was noted. Then it was placed in the beam of radiation from the 130-ton betatron for a few minutes. Because of the danger from this radiation no one was allowed in the room with it while the exposure was taking place. But when the half dollar was again put in the counter, there was a steady roar, the clicks coming about 10,000 times per minute. After a few minutes, however, this slowed down and finally ceased, as a result of the decay of the radioactivity.

What happens in the coin is an actual transmutation of some of the atoms of silver to other elements. According to Dr. Stanley Klaiber, research associate in the Research Laboratory, the rays from the betatron knock a neutron from the nucleus of a silver atom. This changes it from ordinary silver, with mass of 109 units, to another kind or isotope, weighing only 108 units. This isotope is unstable. It gives off an electron, which increases its positive electrical charge by one unit. Since it is the electrical charge of the nucleus that determines what element it is, this means that it is no longer silver, but has been transmuted to cadmium.

The electrons given off while this transmtation is taking place are responsible for the roar heard in the Geiger counter. After 2.3 minutes half of the silver 108 nuclei are changed, and in the course of a quarter of an hour their number is reduced so much that there is no appreciable activity left. There is, however, a much weaker process due to the change of another isotope of normal silver, of mass 107, to silver 106 and thence to palladium. This is done with the emission of a positive electron, which reduces the positive charge of the nucleus by one unit. Also, the copper, constituting about 10 per cent of coin silver, undergoes a change from its normal mass of 63 to 62, and is then

transmuted to nickel. Since all of these activities die off rapidly, the coin is not dangerous after an hour or so.

Although these changes involve huge numbers of atoms, they are exceedingly small in proportion to all the atoms in the coin, and no chemical test could detect the cadmium, nickel or palladium produced. Thus, the composition of the coin is not perceptibly altered.

R. H. O.

Products in Paper, Plastics, Abrasives, and Paint Fields are Improved by the Incorporation of New Fiberglas Milled Fibers.—Research now being conducted in the laboratories of Owens-Corning Fiberglas Corporation and in the laboratories of other manufacturers points to numerous uses of a new material—Fiberglas milled fibers—as a reinforcing agent for special papers, plastics and abrasive compounds. The milled fibers have also been employed successfully to improve the sound deadening characteristics of sound deadening paints.

Fiberglas milled fibers are formed by hammermilling Fiberglas continuous yarns into maximum lengths ranging from one thirty-second of an inch to one and one-half inches. Diameter of the fibers, in all lengths, is 25 one-hundred-thousandths (0.00025) of an inch. Appearance of the fibers varies with the maximum fiber length. The shortest lengths are tightly nodulated, while the longest sizes form a loose mass.

The tear strength of explosive paper, used for wrapping dynamite, is materially increased by the addition of 10 per cent., by weight, of three-quarter-inch milled fibers. The presence of the glass fibers provides a better bond between the paper and the paraffin used to coat it. Hinging action is minimized. Because dispersion of the glass fibers in the paper gives it more uniform strength, the paper disintegrates after the explosion, instead of leaving small pieces to smolder and perhaps cause a fire.

Ten per cent., by weight, of the milled fibers dispersed in filtering paper gives it more uniform capillarity and speeds the filtering process. The fibers are highly adsorbent (not absorbent) and act as veins which conduct moisture rapidly throughout the paper. Because of his high adsorption characteristic, the same percentage of the fibers in laminating paper speeds impregnation by the resin and reduces curing time.

Fiberglas milled fibers have been successfully incorporated in high-pressure resins (melamine) to form molded plastic switch boxes. Tests show that the product has increased impact strength, an arc resistance of 183–186 seconds of flash in contrast to from 2 to 5 seconds of flash when other fillers are used, and that when burned (A.S.T.M. test) there is a weight loss of only 3 per cent. as compared to the 30 per cent. weight loss when other fillers are incorporated in the resin. These improved characteristics indicate that the milled fibers are adaptable to many other applications in the high-pressure molded plastics field.

A 300 to 400 per cent. improvement in impact strength and generally longer life have been given phonograph records by replacing organic filler material with 3 per cent., by weight, of the one-eighth-inch Fiberglas milled fibers. Record deterioration is frequently due to the presence of microscopic blisters in the sound track. Such blisters are attributable to swelling of organic filler

material, caused by moisture absorption. Since the milled Fiberglas fibers are microscopically fine solid glass rods they can neither absorb moisture nor swell. No increase in the noise level is caused by the presence of the glass fibers. Phonograph records are customarily made of a compound of silica flour, shellac, lamp black and filler material.

Strength and performance of abrasive cutting wheels have been improved by incorporation of one-quarter-inch Fiberglas milled fibers in the abrasive grain (chopped silica, carborundum, etc.) which is mixed with a thermo-setting binder and molded into form. Addition of the milled fibers has increased by 25 per cent. the strength of 12-inch-diameter, one-eighth-inch-thick wheels used to cut the bead off molded metal products. Top operating speed has been increased from 15,000 to 17,000 revolutions per minute. The heat generated is dissipated rapidly and no tendency to burn the metal is shown.

Fiberglas milled fibers ranging from one-sixteenth to one-thirty-second of an inch in length have been incorporated in sound deadening paints, with a resulting improvement of 100 per cent. in sound deadening qualities. The paints, sprayed on metal surfaces, "de-ping" the metal by reducing the vibration. Their chief field of use is in the automotive industry where they are applied to the interior metal surfaces of passenger cars, trucks and other automotive vehicles.

R. H. O.

Foresees Many Atomic Power Applications.—Many of the proposed applications of atomic power—even for interplanetary rockets—seem to be within the realm of possibility provided the economic factor is ruled out completely, and the doubtful physical and chemical factors are weighted heavily on the optimistic side.

So declared Dr. C. G. Suits, vice president of the General Electric Company and director of its Research Laboratory, who spoke at a meeting of the American Institute of Electrical Engineers.

"Which of these possible applications of atomic, or nuclear, energy is likely to become practical, and when, depends on the amount of research, development and engineering effort, which we can devote to these physical factors in the immediate future," he declared.

"We have, during the war," he continued, "largely used up our accumulated surplus of basic knowledge of the atomic nucleus. The dividend was the atomic bomb. We must, without further delay, restore this surplus in preparation for the important peacetime job for the nucleus—power production.

"The development of economical atomic power is not a simple extrapolation of knowledge gained during the bomb work. It is a new and difficult project and great effort will be required to reach a satisfactory answer."

A chain-reacting pile, containing uranium or another of the elements that undergoes the energy-releasing process of fission, together with the moderators of "slower-downers," was used to make some of the elements used in the bomb. Such a pile, Dr. Suits pointed out, may be used to produce controllable heat energy, but some of the products given off are very dangerous and the radiations from it necessitate shielding equivalent to several feet of steel. Furthermore, it must contain a certain minimum amount of material before it will

work at all. For such reasons, he said, "small fission power plants appear now to be out of the question and a minimum size of perhaps 50 tons is required.

"The fact that such piles must be large," he continued, "immediately rules out a host of lower power applications. Automotive power is out. Railroad locomotive power is almost certainly out. Large ship propulsion seems not only possible but attractive, though on a strategic rather than a competitive basis. Perhaps large electric power plants are in the running in areas, for example, Australia, where there is practically no conventional fuel, but abundant natural resources of many other types.

"Atomic power plants for electric power generation will probably at some time in the distant future compete successfully with coal, oil and water power energized plants," he predicted. "In fact, this ultimate possibility is an important hedge against the ultimate exhaustion of the natural oil and coal reserves."

Dr. Suits warned, however, that there is nothing in sight at present which leads us to suppose that atomic energy may be converted directly to electrical energy, and that on the contrary a nuclear pile will probably operate as the heat source of a conventional electric power generating system. Under present conditions, the cost of fuel is only about a quarter of the whole cost of power production, and therefore "a reduction in the cost of fuel to zero would not provide a spectacular reduction in the cost of electric power."

He urged that "development programs directed toward the use of nuclear energy for power production be undertaken by all branches of the power industry, probably with governmental support, but not in the anticipation of quick application in competition with conventional fuels. A large amount of fundamental research in nuclear and related fields also will have to be done in support of the long range program. Since much of the equipment required in nuclear research today, such as cyclotrons and betatrons, is large and expensive, it will be necessary for the government to support the fundamental program too, if it is to progress at an adequate rate."

Exploring nuclear reactions in the higher energy ranges may prove the key to usage of atomic energy much more efficiently than by the fission process, Dr. Suits indicated. Fission only gives us about one thousandth of the potential energy—some 10 billion kilowatt hours per pound—locked in the nuclei of all kinds of matter. The reactions that occur in the pile are those performed with energies in the range of 10,000,000 volts, while the most energetic laboratory radiation available until recently, obtained with the cyclotron, was under 40,000,000 volts.

With the 100,000,000-volt betatron in the General Electric Research Laboratory, he stated, a whole new energy range between 50,000,000 and 100,000,000 volts, is under investigation.

R. H. O.

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